Washington State Department of Transportation

SR 3 MP 50.85 South Fork Johnson Creek to Johnson Creek (WDFW ID 991241): Draft Preliminary Hydraulic Design Report

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Responsibility: Water Resources Professional Engineer in responsible charge of this Hydraulic Design Report, including all information, calculations, assumptions, modeling, professional judgment, and commitments contained in the main report and appendices.

Authoring Firm PHD QC Reviewer(s)
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Olympic Region GEC Fish Passage/Stream Design Advisor
Responsibility: Water Resources Professional Engineer providing mentorship, process oversight, quality check issue resolution, and recommendations in the approach to hydraulic analysis and design performed by the **PHD Lead PE**. Before submittal of draft deliverables from the GEC to either the PHD Lead or WSDOT Headquarters, the Olympic Region GEC Fish Passage/Stream Design Advisor will review and refine GEC comments and confirm GEC comment resolution by the **PHD Lead PE**.

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1 Introduction

To comply with United States et al. vs. Washington et al., No. C70-9213 Subproceeding No. 01-1 dated March 29, 2013 (a federal permanent injunction requiring the State of Washington to correct fish barriers in Water Resource Inventory Areas [WRIAs] 1 through 23), the Washington State Department of Transportation (WSDOT) is proposing a project to provide fish passage at the State Route (SR) 3 crossing of the South Fork Johnson Creek to Johnson Creek (SF Johnson Creek) at milepost (MP) 50.85 within WSDOT's Olympic Region. The existing structure at that location has been identified as a fish barrier by the Washington Department of Fish and Wildlife (WDFW) and WSDOT Environmental Services Office (ESO) (site identifier [ID] 991241) and has an estimated 5,367 linear feet of habitat gain (WDFW 2004).

Per the federal injunction and in order of preference, fish passage should be achieved by (1) avoiding the necessity for the roadway to cross the stream, (2) use of a full-span bridge, or (3) use of the stream simulation methodology. WSDOT evaluated the crossing and is proposing to replace the existing crossing structure with a structure designed using the confined bridge design methodology due to the floodplain utilization ratio (FUR) being less than 3.0.

The crossing is located in Kitsap County, 4 miles west of Poulsbo, Washington, in WRIA 15 (Washington State Department of Ecology [Ecology] n.d.). The highway runs north-south at this location and is about 1 mile upstream of the confluence with Johnson Creek. SF Johnson Creek generally flows west to east, beginning approximately 1 mile upstream of the SR 3 crossing (Figure 1).

The proposed project will replace the existing 36-inch-diameter, 400-foot-long, corrugated steel pipe with a structure designed to accommodate a minimum hydraulic opening of 20 feet with a structure-free zone of 30 feet or greater. The proposed structure is designed to meet the requirements of the federal injunction using the confined bridge design methodology (WSDOT Headquarters [HQ] Hydraulics suggests a bottomless, three-sided structure) as described in WDFW's 2013 *Water Crossing Design Guidelines* (WCDG; Barnard et al. 2013). This design also meets the requirements of WSDOT's *Hydraulics Manual* (2022).

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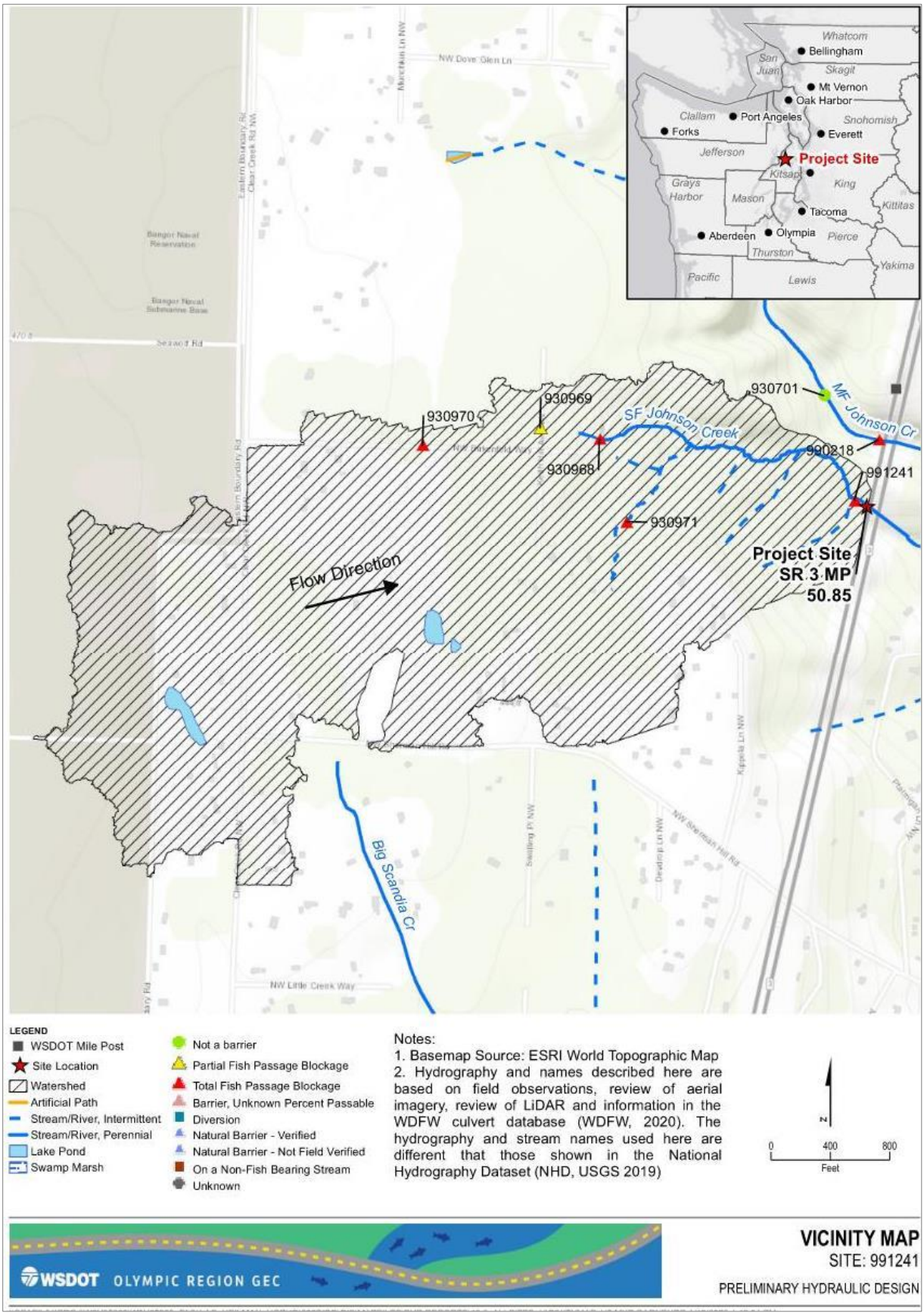

Figure 1: Vicinity Map

2 Watershed and Site Assessment

The existing watershed was assessed in terms of land cover, geology, regulatory floodplains, fish presence, site observations, wildlife crossing priority, and geomorphology. This was performed using a site visit and desktop research with resources such as the U.S. Geological Survey (USGS), Federal Emergency Management Agency (FEMA), and WDFW and past records such as observations, maintenance, and fish passage evaluation.

2.1 Site Description

The August 2004 WDFW Level A Culvert Assessment Report found that the existing culvert crossing is a full fish barrier due to slope (8.0 percent) with a 0 percent passability (WDFW 2004). Field observations indicate that the size of the culvert also likely limits transport of debris—both sediment and large woody material (LWM). Interrupting these processes results in moderate degradation of available fish habitat downstream by starving downstream reaches of sediment and LWM while the upstream reach cannot be accessed by migration. The actual culvert slope was measured at 7.1 percent, per recent WSDOT survey (2021a). WDFW's report identified this area as a reach that could gain 8,504 square feet of spawning habitat, 38,546 square feet of rearing habitat, and a river length of 5,367 feet (1 mile) upstream of the crossing by improving the SR 3 crossing (WDFW 2004).

Maintenance and emergency repair history for this crossing was requested, but WSDOT indicated there none are available for this crossing. Additionally, this site is not classified as a Chronic Environmental Deficiency or failing structure by WSDOT HQ Hydraulics.

The project is not within a special flood hazard area or mapped FEMA floodplain, as shown in Appendix A. The area is designated as Zone X - area of minimal flood hazard (FEMA 2017). Additionally, there was no noticeable flood history at the existing SR 3 crossing due to the steep channel. Future design should consider discussing the flooding history of the existing downstream Ptarmigan Lane NW crossing (WDFW ID 991905), located approximately 400 feet downstream of the SR 3 crossing, with nearby local landowners.

2.2 Watershed and Land Cover

SF Johnson Creek[1] flows in an easterly direction, crossing SR 3 at MP 50.85, joining Johnson Creek approximately 1 mile downstream of the SR 3 crossing, and flowing into Liberty Bay about 1.1 mile downstream of the SR 3 crossing. SF Johnson Creek does not include any major named tributaries upstream of the SR 3 crossing. A combination of gridded light detection and ranging (LiDAR) topography and field observations by Jacobs Engineering Group Inc. (Jacobs; the design team) were used to define the watershed boundary (Figure 2), resulting in a delineated watershed area of approximately 240 acres (0.37 square mile).

[1] Hydrography and names described herein and shown on Figure 1 are based on field observations, aerial imagery review, LiDAR review, and information in the WDFW culvert database (WDFW n.d.-b). The hydrography and stream names used herein are different than those shown in the National Hydrography Dataset (USGS 2019).

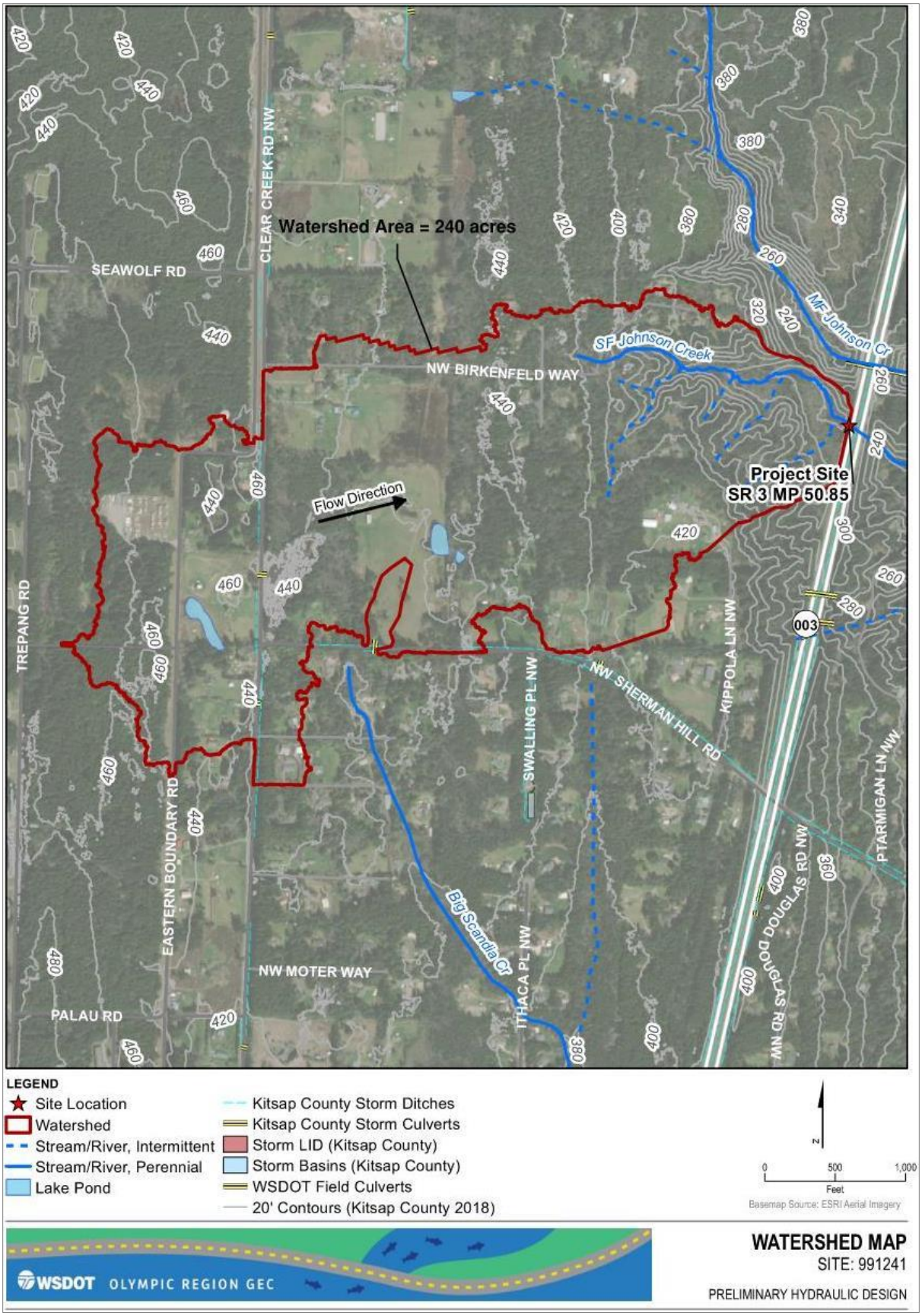

Figure 2: Watershed Map

The SF Johnson Creek watershed ranges in elevation from 475 to 222 feet using NAVD83 (North American Vertical Datum of 1983) as the vertical datum. It consists of moderately sloped terrain in the western portion of the watershed and high-sloped terrain in the eastern portion of the watershed (Figure 3). Land use was evaluated using the National Land Cover Dataset (Multi-Resolution Land Characteristics Consortium [MRLC] 2019a), National Urban Imperviousness Dataset (MRLC 2019b), and visual interpretation of aerial imagery (ESRI n.d.). Most of the eastern portion of the watershed is used as forested area with some single-family residences. Clear Creek Road divides the western quarter of the basin, which encompasses additional residential land and a portion of Bangor Naval Base. Topography was used as the basis of the basin boundary rather than roads or storm water systems. Additionally the upper portion of the watershed appears unchannelized, so assumptions are made about flow direction and dynamics then further described in Section 3. A shallow valley bisects the basin. The land cover is about 52 percent forest, 10 percent pasture/hay, and 31 percent developed (Figure 4), with the remainder consisting of emergent herbaceous and woody wetlands, as identified in Table 1. Total impervious area is approximately 7 percent of the watershed, based on analysis of National Land Cover Dataset (MRLC 2019b).

Table 1: Land cover

Land cover class	Basin coverage (percentage)
Barren Land	0%
Deciduous Forest	3%
Developed, High Intensity	1%
Developed, Low Intensity	9%
Developed, Medium Intensity	1%
Developed, Open Space	20%
Emergent Herbaceous Wetlands	2%
Evergreen Forest	35%
Grassland/Herbaceous	0%
Mixed Forest	16%
Open Water	0%
Pasture/Hay	10%
Shrub/Scrub	0%
Woody Wetlands	3%

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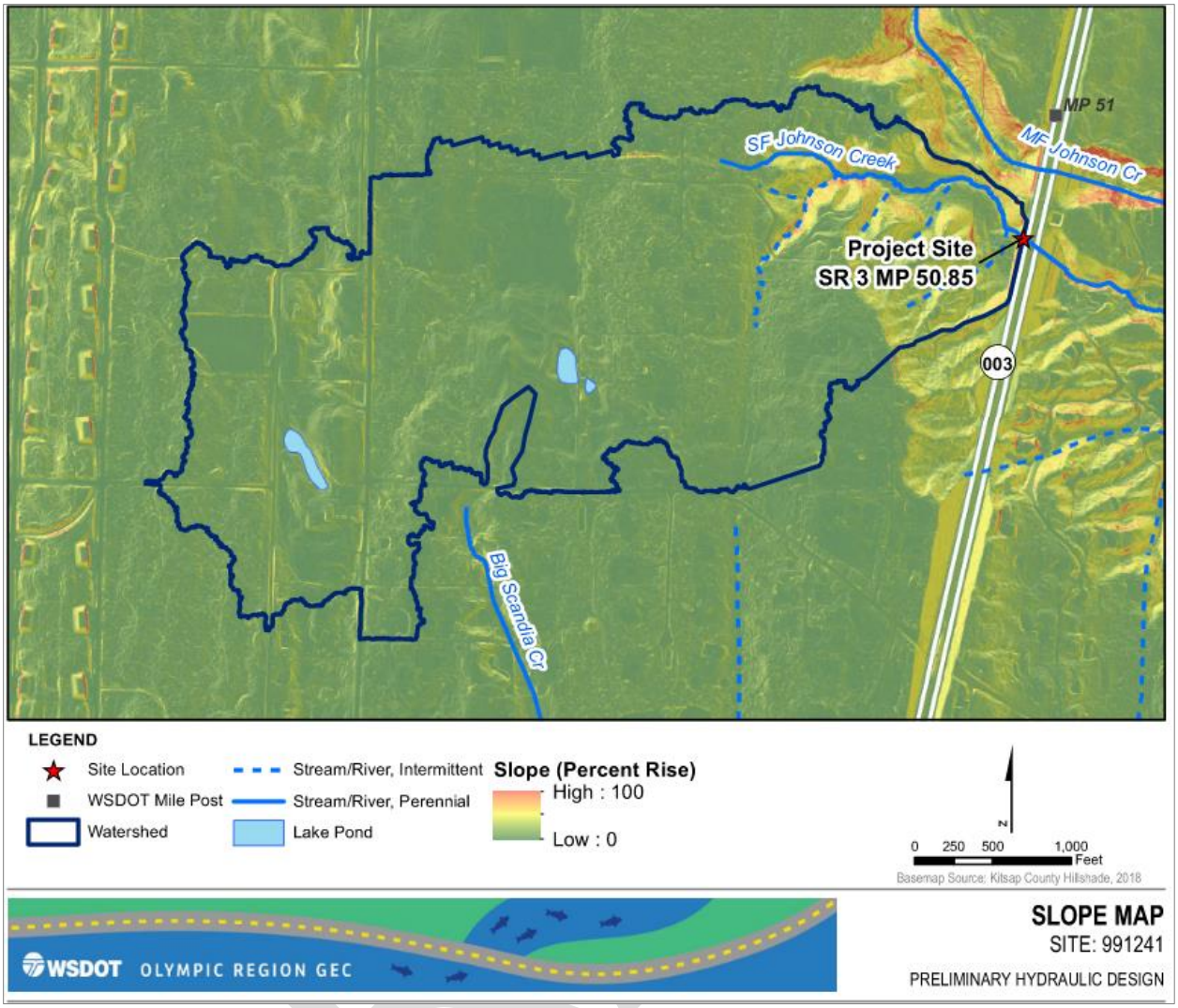

Figure 3: Existing Slopes

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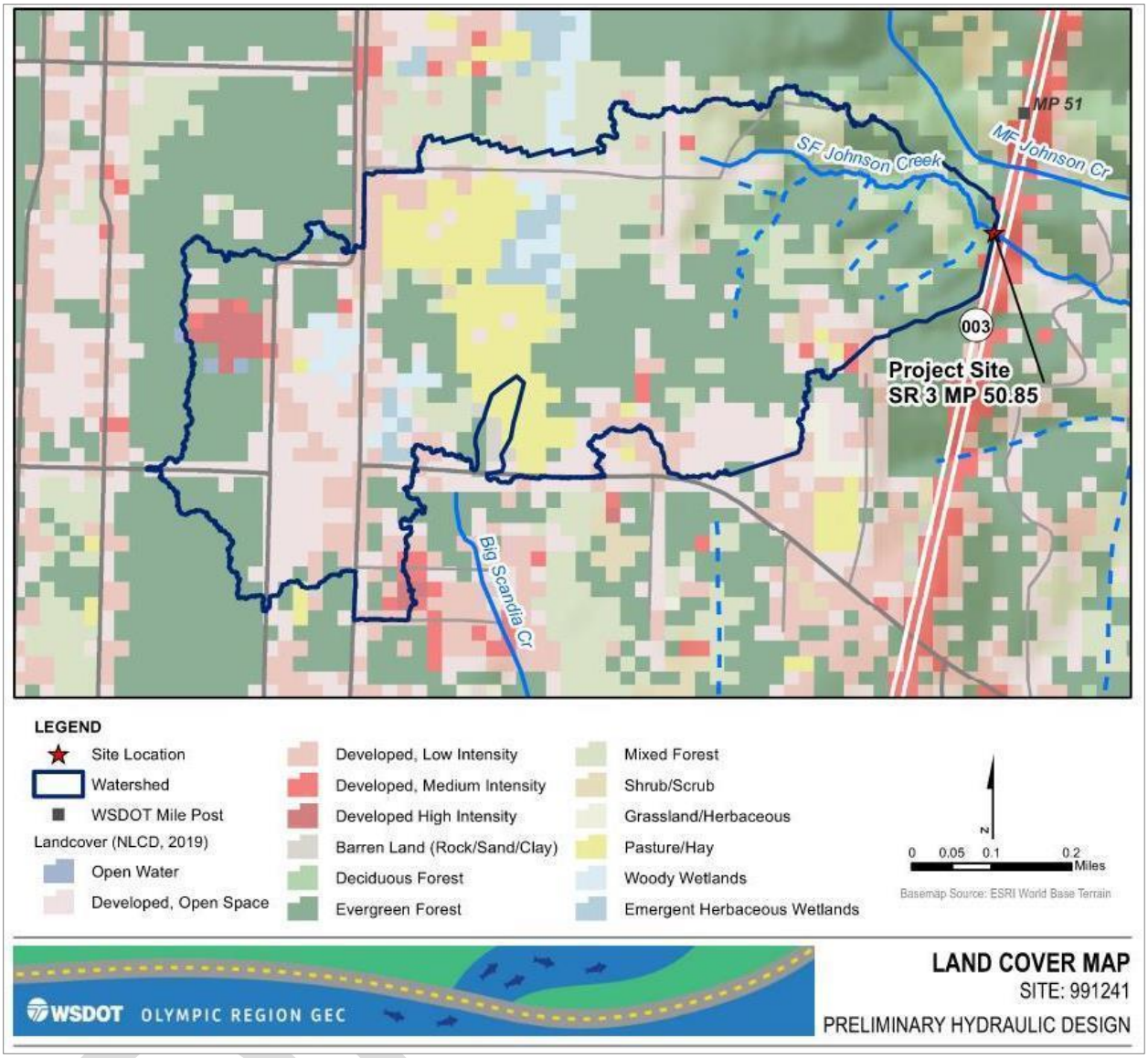

Figure 4: Land Cover Map

2.3 Geology and Soils

SF Johnson Creek drains a basin composed primarily of Pleistocene glacial deposits, with significant exposures of Quaternary mass-wasting deposits on the south side of the channel (north-facing slopes) (Figure 5; Natural Resources Conservation Service, U.S. Department of Agriculture [NRCS USDA] 2021). The glacial deposits, which dominate the basin, had their source in Pleistocene-era continental glaciation and provide an abundant source of sediment, especially in areas mapped as glacial drift, which in this area has been identified as recessional outwash, consisting of unconsolidated sands and gravels. While glacial till is consolidated and generally promotes rapid runoff, glacial outwash allows water to infiltrate and be stored as shallow groundwater. Much of the upper watershed mapped as glacial till is a low relief surface with disorganized drainage pattern, evidenced by the presence of small, internally draining ponds (closed depressions). A brief examination of the LiDAR-generated hillshade imagery shows older, mass-wasting scarps on upstream hillslopes, but no nearby fresh scarps were observed in the area mapped as mass-wasting. No bedrock was observed during Jacobs' fieldwork. Although the presence of mass-wasting deposits and sediment-producing rock units indicates high sediment supply, no field indicators of transport-limited conditions were observed. In other words, the transport capacity of the channel at the crossing appears to roughly match the incoming sediment supply.

Soils in the SF Johnson Creek Basin consist primarily of Alderwood gravelly sandy loam, a moderately well-drained soil that is generally formed from glacial drift and/or glacial outwash over dense glaciomarine deposits (Figure 6; NRCS USDA 2021). Soil types and the underlying geology, along with land use and cover, were used to develop a hydrologic model of the basin, discussed in Section 3. The geotechnical scoping memorandum from the WSDOT Geotechnical Office (2021b) indicates that the in situ material nearest the inlet and outlet consists of coarse-grained glacial deposits. These deposits were described as dense but cohesionless silty gravel and silty sand. By Hydraulic Engineering Circular 18 (HEC-18) criteria (Arneson et al.), erodibility of this material was rated "very high."

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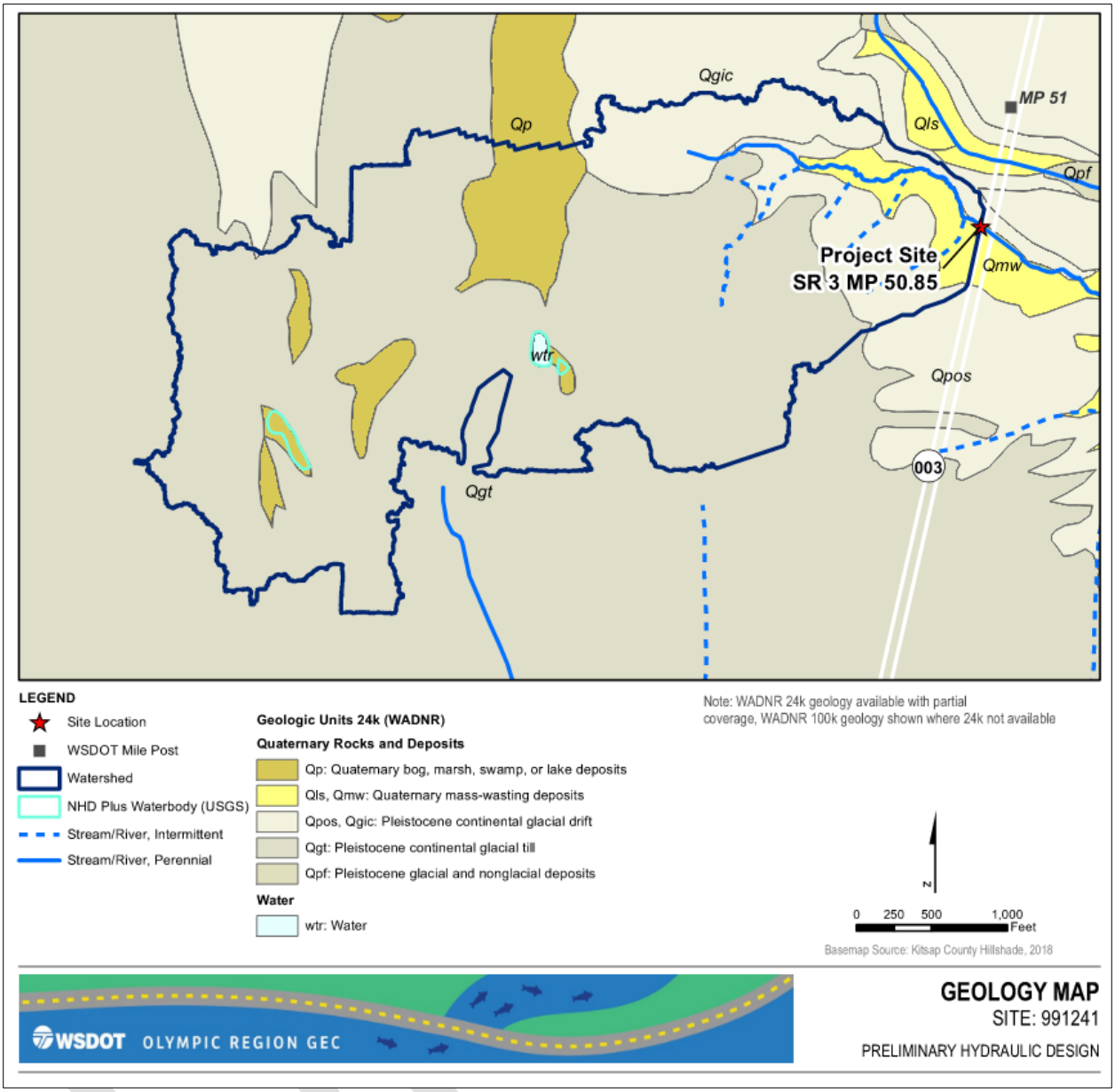

Figure 5: Geologic Map

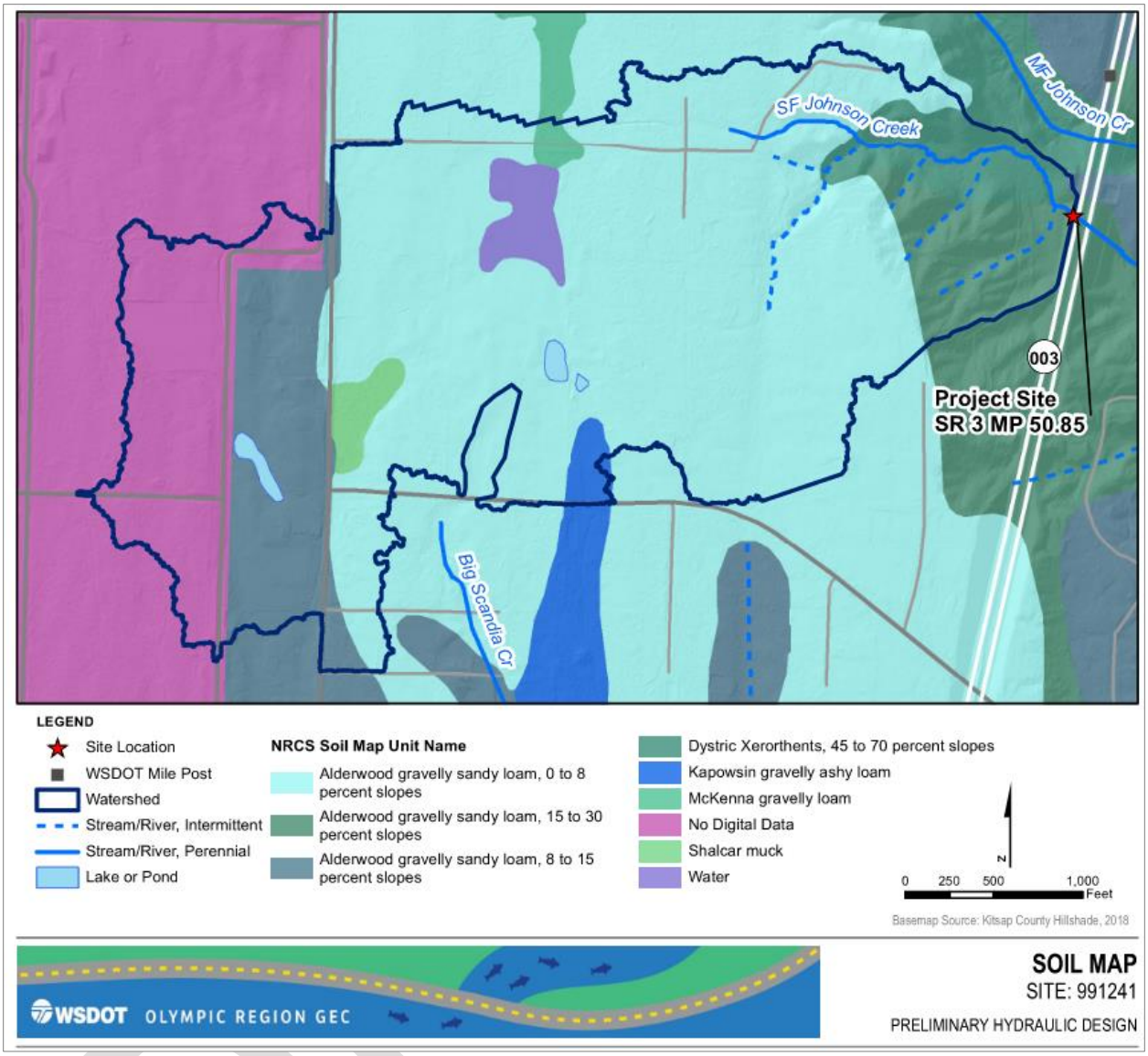

Figure 6: Soils Map

2.4 Fish Presence in the Project Area

Jacobs staff reviewed multiple publicly available information sources regarding historic and current fisheries resources and distribution within the project area, including the following:

- WDFW Fish Passage and Diversion Screening Inventory (n.d.-a), which includes a compilation of barrier and habitat assessment reports
- WDFW Fish Passage and Diversion Screening Inventory Database, Level A Culvert Assessment Report for South Fork Johnson Creek (2004)
- Statewide Washington Integrated Fish Distribution (SWIFD) database (Northwest Indian Fisheries Commission [NWIFC] n.d.)
- Ecology Watershed Restoration and Enhancement Draft Plan, WRIA 15 Kitsap Watershed (2021)
- National Marine Fisheries Service (NMFS) Essential Fish Habitat (EFH) Mapper (n.d.)
- WDFW APPS Hydraulic Project Approval database search by Section/Township/Range (n.d.-c; no projects within the vicinity)
- Washington State Recreation and Conservation Office project database search by WRIA (n.d.; no projects within the vicinity)
- Site observations by Jacobs biologist on December 1, 2021

Jacobs representatives, including a fisheries biologist, conducted the initial site visit on December 1, 2021, to document the existing conditions of the channel upstream and downstream of the crossing. Streams with a channel width greater than 2 feet and a contributing basin larger than 50 acres in Western Washington are presumed to have fish use (Washington Administrative Code [WAC] 222-16-131).

Streams with existing or historic fish use within this region are mapped as EFH for Pacific salmon under the Magnuson-Stevens Fishery Conservation and Management Act; therefore, SF Johnson Creek is included as EFH for Pacific salmon. SF Johnson Creek is not listed as designated critical habitat for aquatic species under the federal Endangered Species Act.

SF Johnson Creek has the potential to support native resident and anadromous salmonids both upstream and downstream of the existing crossing. Suitable habitat supporting migration, spawning, and rearing is present in the upstream and downstream reaches with the potential to support all life stages of resident and anadromous salmonids indicated in Table 2. Chum (*Oncorhynchus keta*), Chinook (*Oncorhynchus tshawtyscha*), pink (*Oncorhynchus gorbuscha*), sockeye (*Oncorhynchus nerka*), and bull trout (*Salvelinus confluentus*) were not documented to occur or modeled as potentially occurring in SF Johnson Creek by WDFW (2004). Section 2.6.3 discusses fish habitat quality in greater detail, including fish utilization by life stages. Table 2 summarizes aquatic species that are documented to occur within the project area based on this data review.

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Table 2: Native fish species potentially present within the project area

Species	Presence (presumed, modeled, or documented)	Data source	ESA listing
Puget Sound Steelhead (*Oncorhynchus mykiss)*	Modeled- Gradient Accessible Potential	SWIFD Web App WDFW Fish Passage Report	Threatened, NMFS
Coho Salmon (*O. kisutch*)	Modeled- Gradient Accessible Potential	SWIFD Web App WDFW Fish Passage Report	Not Listed
Cutthroat Trout (Sea Run) (*O. clarkii clarkia*)	Modeled- Gradient Accessible Potential	SWIFD Web App WDFW Fish Passage Report	Not Listed
Cutthroat Trout (Resident) (*O. clarkii clarkia*)	Modeled- Gradient Accessible Potential	SWIFD Web App WDFW Fish Passage Report	Not Listed

Sources: SWIFD n.d.; WDFW 2004.

2.5 Wildlife Connectivity

The 1-mile-long segment that SF Johnson Creek falls in is not ranked for Ecological Stewardship and is medium priority for Wildlife-related Safety by WSDOT HQ ESO. Adjacent segments to the north and south are ranked low. A wildlife connectivity memorandum will not be provided at this site. On July 26, 2022, Jacobs met with the habitat connectivity team to discuss wildlife connectivity purposes at this site. While an official memorandum has not been provided, the habitat connectivity team noted that deer are the anticipated design species for this site, where the target openness ratio of the proposed crossing should be 2.0 with an ideal minimum hydraulic opening of 20 feet. Due to the deep roadway fill, the target openness ratio should be taken into consideration at this site and is discussed in Sections 4.2.2 and 4.2.3.

2.6 Site Assessment

2.6.1 Data Collection

On December 1, 2021, Jacobs staff investigated approximately 300 feet upstream of the culvert inlet and 300 feet downstream of the culvert outlet. A total of five pebble counts, two upstream, two downstream, and one in the reference reach were performed.

The reference reach and bankfull width (BFW) concurrence site visit with WDFW and the Tribes occurred on December 17, 2021. The group agreed that it was reasonable to have a BFW of 7 to 9 feet for the proposed design based on the reference reach, discussed further in Section 2.7.1. After the concurrence meeting, Jacobs staff remained and collected additional information in the newly selected reference reach, including BFW measurements, step-pool details, pebble count, and LWM in the system.

The topographic survey data collected by WSDOT in September 2021, extends approximately 300 feet upstream and downstream of the existing SR 3 crossing. Figure 7 shows the locations of all BFW measurements, pebble counts, and the reference reach location. Further detail on sediment is explained in Section 2.7.3. Thirteen BFW measurements were collected and are explained further in Section 2.7.2. Field reports for the December 1 and December 17 site visits are provided in Appendix B.

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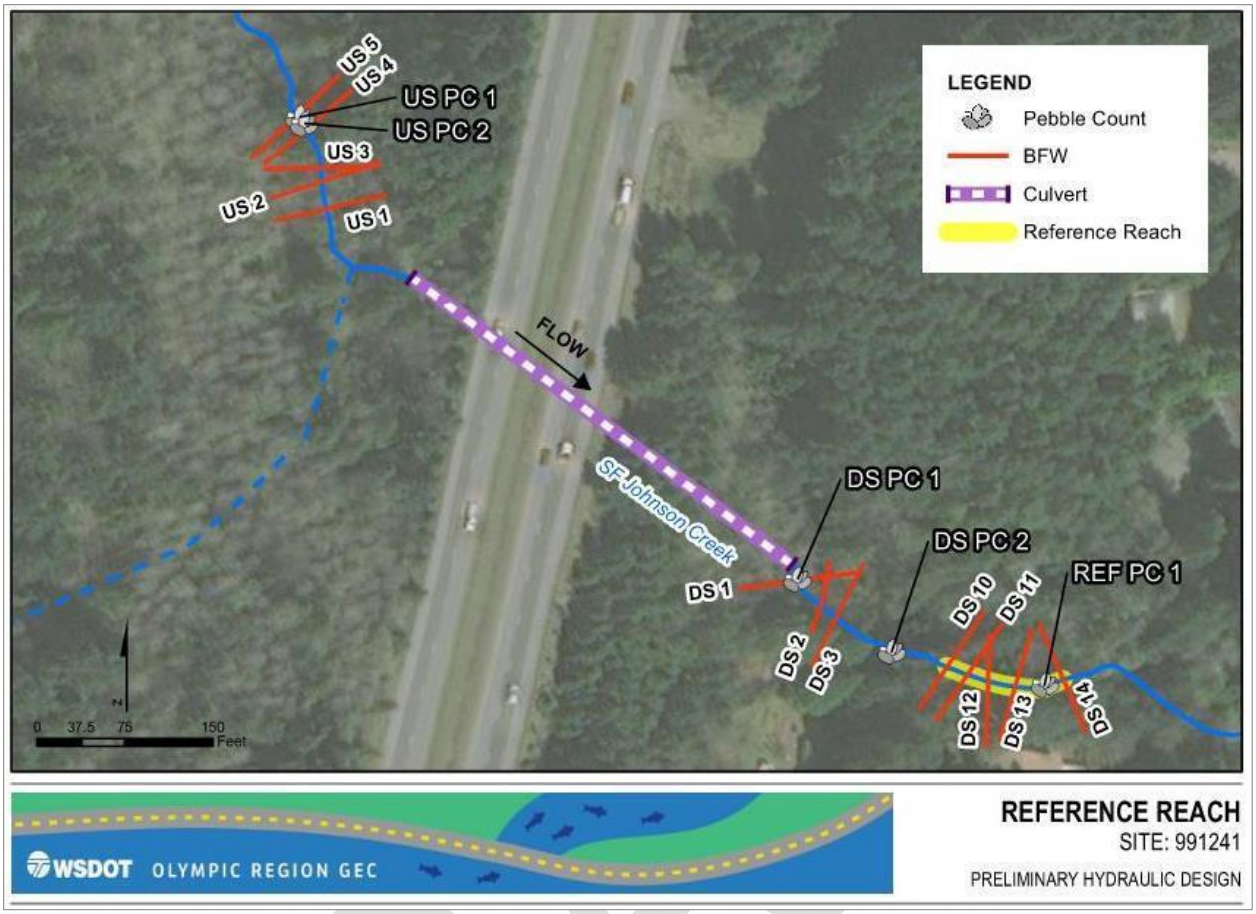

Figure 7: Reference reach, bankfull width, and pebble count locations

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2.6.2 Existing Conditions

The existing crossing consists of a 36-inch-diameter, 400-foot-long, corrugated steel pipe that runs west to east at a skew to the highway with an overall gradient of 7.1 percent. There is approximately 60 to 80 vertical feet between the culvert crown and the road surface (Figure 8). Aside from the large walls for SR 3 at the inlet and outlet, the other infrastructure noted in the vicinity of the crossing is Ptarmigan Lane NW and a stormwater pond to the north of the crossing. Ptarmigan Lane NW runs perpendicular to SF Johnson Creek approximately 400 feet downstream of the project crossing and the stormwater pond appears to discharge away from the project site. As-builts for the existing SR 3 culvert were obtained from WSDOT HQ and showed that, in 1980, the existing 36-inch crossing was placed at 7 percent.

Upstream of the crossing, the channel has minimal sinuosity due to the surrounding steep valley walls for 150 feet until the culvert inlet where the channel has one meander bend with a radius of curvature of 27 feet. The channel is a low gradient (3 to 4 percent), wetland-like reach with indistinct banks, few streamside conifers, and relatively wide/shallow geometry. Backwater conditions at the crossing inlet appear to drive a poorly defined bankline and wide and shallow channel shape.

Downstream of the crossing, the channel emerges from the outlet down a short, steep slope with riprap (2 feet in size). Farther downstream, the channel included undercut banks and a mix of legacy coniferous LWM in various stages of decay and newer deciduous LWM that has formed some pool sections (Figure 9). The longitudinal slope of the channel varies from 4 to 9 percent in the downstream reach. With the exception of the vegetation clearing performed to facilitate the site survey, no obvious signs of maintenance were noted.

Information on existing riparian vegetation conditions, LWM, and canopy cover is in Section 2.6.4. As noted in Section 2.1, the August 2004 WDFW Level A Culvert Assessment Report found that the existing culvert crossing is a full fish barrier due to slope (8.0 percent) with a 0 percent passability (WDFW 2004). Field observations indicate that the size of the culvert also likely limits transport of debris—both sediment and LWM. Interrupting these processes results in moderate degradation of available fish habitat downstream by starving downstream reaches of sediment and LWM while the upstream reach cannot be accessed by migration.

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Figure 8: Existing 36-inch inlet with vertical wall

Figure 9: Typical channel downstream of crossing

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2.6.3 Fish Habitat Character and Quality

SF Johnson Creek is noted in data sources as having both intermittent and/or perennial flow (NWIFC n.d.; WDFW 2004; WSDOT 2021a). Stream characterizations, including a well-defined channel, clean gravel substrate, and lack of vegetation below ordinary high water, suggest that this waterbody flows perennially throughout the majority of the year and may be mapped incorrectly as intermittent. It is possible during extended periods of drought in the summer that surface flows diminish but interstitial pools are likely to remain that could sustain aquatic organisms, including juvenile salmonids.

Instream habitat conditions within the upstream reach of the project area consists of a riffle-run to riffle-pool habitat type, with pools created by legacy coniferous LWM as well as more recent deciduous LWM and riparian tree roots. Pools were intermittent and ranged in depth from 6 inches to 1 foot. Pools were more abundant upstream of the wetland-like reach where LWM is more abundant. At the upstream-most extent of the surveyed area, the stream runs under a large legacy LWM complex approximately 20 feet long and covered with topsoil and vegetation. A pool under this complex is evident given the gravel tailout, where the stream emerges (Figure 10). The pool under this complex may be the deepest pool within the surveyed reach but was inaccessible. Instream habitat conditions in the downstream reach is a confined riffle-run reach, with fewer key LWM pieces, resulting in lower in-channel complexity, including fewer pools and no floodplain bench. Instream substrate within both reaches consists primarily of small- to medium-sized gravels with a lower percentage of coarse sand. Streambed gravels were clean and free from algae or moss, which may be an indicator of perennial flow. The overall substrate is suitable for spawning as it contains a mixture of sands and gravels.

The stream width, depth, gradient, and substrate is suitable for rearing, migration, and spawning of resident and sea-run cutthroat trout and may be suitable for migration and spawning of anadromous salmon. Depending on the timing of adult salmon returns, the water depth during periods of low water may be a limiting factor for migrating adult anadromous salmon (including steelhead and coho). Rearing habitat for all resident and anadromous juvenile fish is present, though limited by low to moderate presence of pools, particularly within the downstream reach. Section 2.6.4 provides additional information on riparian conditions.

Figure 10: Upstream reach, facing upstream. Legacy LWM providing a lateral pool.

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2.6.4 Riparian Conditions, Large Wood, and Other Habitat Features

Riparian vegetation within the upstream reach consists of predominantly native deciduous trees and shrubs along the steep roadway fill associated with the SR 3 retaining wall. This community is dominated by red alder (*Alnus rubra*), salmonberry (*Rubus spectabilis*), and sword fern (*Polystichum munitum*). The vegetation outside of the influence of the road fill consists of mature, closed-canopy, mid-late successional, mixed canopy riparian vegetation community with a width of greater than 150 feet on either side of the stream for the extent of the survey. Dominant species include Western red cedar (*Thuja plicata*), Western hemlock (*Tsuga heterophylla*), big-leaf maple (*Acer macrophyllum*), red alder, salmonberry, devil's club (*Oploplanax horridus*), salal (*Gaultheria shallon*), red huckleberry (*Vaccinium parvifolium*), sword fern, lady fern (*Athyrium filix-femina*), and piggyback plant (*Tolmiea menziesii*). Riparian vegetation within the downstream reach is similar in cover density and composition to the upstream reach depicted on Figure 11.

The presence of large coniferous stumps over 36-inch in diameter at breast height (DBH) with springboard notches indicate this area, like most of the Pacific Northwest, was logged by the early twentieth century. The majority of the instream coniferous LWM is legacy wood (wood present in the stream prior to widespread logging). Removal of the majority of mature conifers in the first half of the twentieth century removed a generation of instream large coniferous wood recruitment potential. The existing closed canopy consists of mature, primarily coniferous tree species ranging from 18- to 24-inch DBH with some western red cedars over 36-inch DBH. These trees likely regenerated within the last 100 years and are of similar age, consistent with early twentieth-century, postindustrial logging regrowth. The expectant life span of these coniferous tree species can exceed several hundred years; therefore, outside of environmental disturbance, these stands would not be expected to serve as significant LWM recruitment potential due to their longevity.

Environmental disturbance such as periodic windfall and disease would be the more likely pathways for LWM recruitment than age-induced decay. Existing instream LWM is a mix of legacy coniferous wood and more recent deciduous material (Figure 12). There is a greater amount of LWM in the upstream reach than the downstream reach. The presence of LWM and corresponding pools for salmonid refugia and cover in both reaches is moderately deficient (upstream reach) to deficient (downstream reach) as compared to the target number of key pieces of LWM for Western Washington (WSDOT 2022; Fox and Bolton 2007). No evidence of beaver activity was noted. A derelict barbed-wire metal fence is situated across and within the channel at the uppermost extent of survey within the upstream reach.

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Figure 11: Upstream reach, closed canopy overstory with a mix of mid-late successional native riparian species. Stream is on lower left.

Figure 12: Upstream reach, facing downstream. Floodplain bench center to right with deciduous LWM across the stream. SR 3 retaining wall in background.

2.7 Geomorphology

Geomorphic information provided for this site includes selection of a reference reach, the geometry and cross sections of the channel, and the vertical and lateral stability of the SF Johnson Creek channel.

2.7.1 Reference Reach Selection

To help inform design of the new channel, an initial reference reach was identified during the site visit on December 1, 2021. The initial reach was upstream of the existing crossing, above the influence of the culvert in a riffle-run reach. However, at the comanager concurrence meeting on December 17, 2021, after viewing the upstream and downstream conditions and discussing alternatives at a high level, the attendees agreed to a "replace in kind" approach with a 7 percent crossing with step-pools in the crossing. This approach is considered the most appropriate to minimize impacts to the surrounding habitat and avoid unnecessary grading upstream and downstream of the crossing.

Due to the chosen approach, a new reference reach—approximately 220 feet downstream of the SR 3 crossing and extending downstream approximately 70 feet—was determined most appropriate (Figure 7). This reach is approximately 100 feet upstream of Ptarmigan Lane NW and had a slope of approximately 5 to 7 percent as determined in the field by a clinometer and confirmed by the survey. The reach is characterized by undercut banks (Figure 13) and a mix of legacy coniferous LWM in various stages of decay and newer deciduous LWM. In-channel LWM facilitated local scour and deposition around individual pieces, as well as localized bank erosion. Gravels scoured around LWM is deposited in the lee of wood pieces and other obstructions. However, erosion is not pervasive and is not creating channel instability such as headcut development or incision, which has formed some pool sections (Figure 14). Owing to the steep slope of the reference reach, floodplain is intermittent, meaning that an adjacent depositional surface created by overbank flows is only occasionally observed. The steepness of the channel commonly retains flows in the channel. Despite this lack of floodplain, the channel exhibits periodic sinuosity as it flows around LWM obstructions.

The reference reach included several deformable (with low stability) steps created by in-channel LWM and racked debris. The pools were generally 5 feet long and spaced on average every 20 feet. At the time of the data collection (December 17, 2021), the change of water surface elevation (WSE) at the steps measured between 0.3 to 0.6 foot. The step that appeared most stable had a 1.2-foot topographic step height, measured from top of step to bottom of pool. Appendix B contains all the metrics collected. The metrics measured in the reference reach were mimicked in the proposed design, further described throughout Section 4.

Stream habitat is suitable for spawning, rearing, and migration of resident and anadromous fish species, though WDFW (n.d.-a) deemed the existing culvert at Ptarmigan Lane NW as 0 percent passable. BFW measurements and pebble counts were taken and are further described in Sections 2.7.2 and 2.7.3, respectively.

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Figure 13: Reference reach, 1-foot undercut bank

Figure 14: LWM in the reference reach

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2.7.2 Channel Geometry

The existing channel exhibits multiple channel types from upstream to downstream of the crossing. Upstream of the crossing, the channel is typically alternating riffles and runs (or glides). The upstream reach exhibits modest sinuosity (1.10 to 1.15) within a wider (approximately 30 to 50 feet) valley bottom. The active floodplain appears to be less than 50 feet wide across the channel. The longer channel length facilitates a flatter channel slope than the downstream reach. The downstream reach is straighter (sinuosity <1.10) within a confined (<100 feet) valley bottom, as well as steeper gradient. In the downstream reach, the channel is typically forced step-pools created by woody debris accumulations separated by short riffles. The downstream floodplain is less than 30 feet wide.

Width-to-depth ratio is a metric that indicates the channel shape. A large width-to-depth ratio (>12 per Rosgen 1994) indicates a wide, shallow channel; a small width-to-depth ratio indicates a narrow, deep channel. The channel shape is different from upstream to downstream. The channel is wider and shallower upstream resulting in a larger (>7) width-to-depth ratio, compared to the downstream channel, which is relatively deep and narrow with a smaller (<5) width-to-depth ratio. Bank heights also differ from upstream to downstream. Upstream, banks are moderately sloped and bank height is commonly low (1 foot), especially near the crossing. Farther upstream, channel banks become taller (1 to 2 feet) and the channel is more entrenched but the banks show no evidence of active failure. Downstream banks are at least 1-foot high and taller. The channel commonly abuts the adjacent right hillslope, which sometimes obscures the presence of a definable bank. Both upstream and downstream banks are composed of matrix-supported material, dominated by fine-grained, cohesive material. This composition increases bank strength.

The marked difference in the characteristics of the upstream and downstream reaches may be related to the presence of mass-wasting deposits along the south side of the channel. Upstream of the crossing, LiDAR-derived contours indicate that slope failures may have deposited material in the valley bottom, creating a wider and flatter valley bottom. Downstream of the crossing, there are also mapped mass-wasting features along the south side of the channel, but the channel appears to have downcut through these deposits.

With respect to channel evolution, using the Cluer and Thorne (2013) model (Figure 15), the upstream reach appears to be in Stage 6, where banks and bankfull stage are being constructed on aggraded material generated by slope failure. The downstream reach appears to be in Stage 3a, where degradation has occurred but is not currently active. Increased slope from the upstream reach to the downstream reach may contribute to incision in the downstream reach.

The locations of the BFW measurement in Table 3 are shown on Figure 7 and include asynchronous numbering. BFWs were measured at 5 to 10 feet in the upstream reach (Figure 16), 7 to 8 feet in the downstream reach (Figure 17), and 7 to 18 feet in the reference reach (Figure 18). Figure 19 depicts the typical BFW cross sections. At the comanager concurrence site visit, a BFW of 7 to 9 feet was agreed upon for structure sizing and for open-channel design portions of the design. BFW DS 12, which measured 18 feet wide, was the only downstream

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BFW not included in the design average as it was abnormally wide due to two midchannel LWM pieces and adjacent hillslope failure. Upstream BFW were not used in the design average because they are not in a reach with a similar slope to the proposed crossing.

Bankfull depths were measured at 0.9 to 1.6 feet in the reference reach. As previously mentioned, the slope of the reference reach is approximately 7 percent. The selected design slope should facilitate uniform flow conditions without sharp transitions in energy grade slope. Consideration of the minimum hydraulic width is also driven by the selection of design slope.

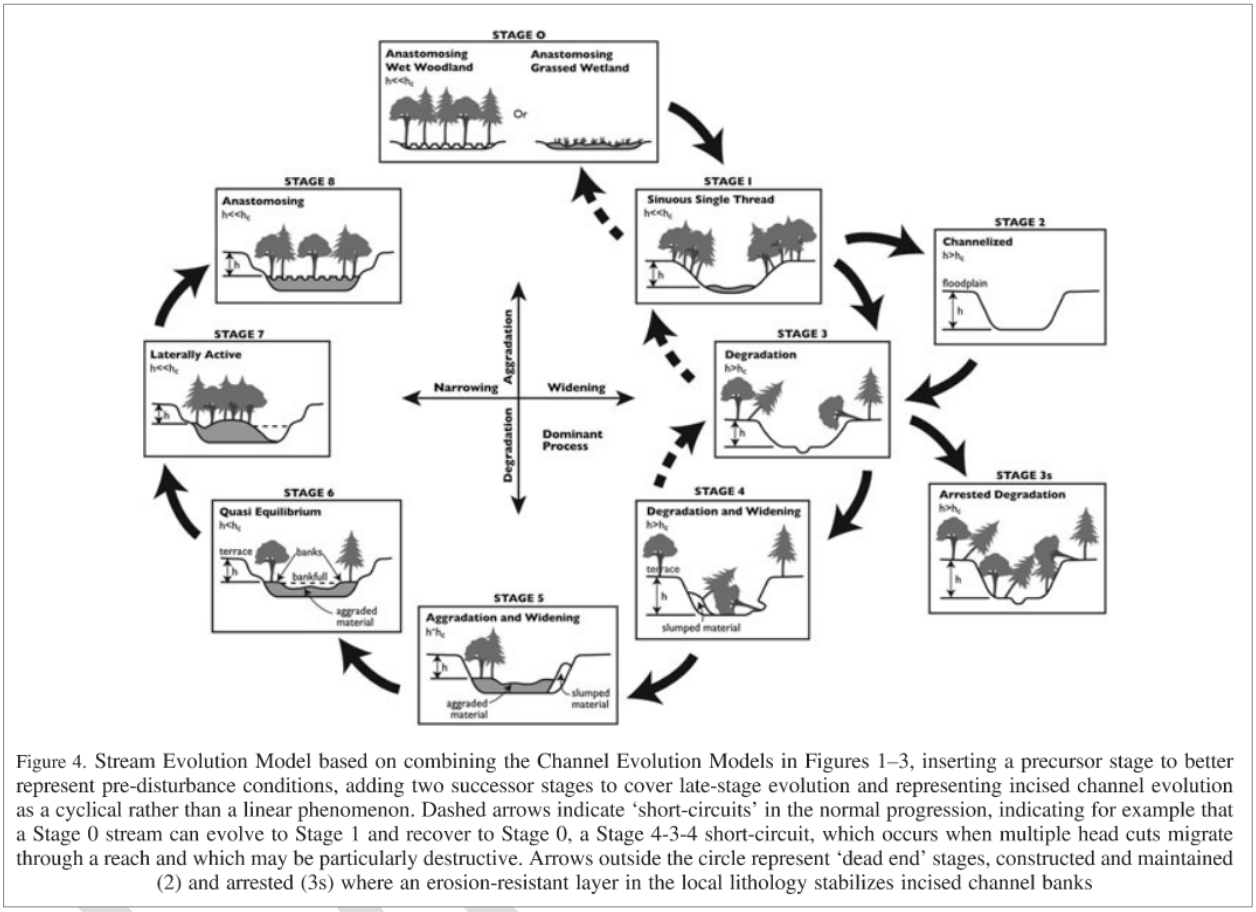

Figure 4. Stream Evolution Model based on combining the Channel Evolution Models in Figures 1–3, inserting a precursor stage to better represent pre-disturbance conditions, adding two successor stages to cover late-stage evolution and representing incised channel evolution as a cyclical rather than a linear phenomenon. Dashed arrows indicate 'short-circuits' in the normal progression, indicating for example that a Stage 0 stream can evolve to Stage 1 and recover to Stage 0, a Stage 4-3-4 short-circuit, which occurs when multiple head cuts migrate through a reach and which may be particularly destructive. Arrows outside the circle represent 'dead end' stages, constructed and maintained (2) and arrested (3s) where an erosion-resistant layer in the local lithology stabilizes incised channel banks

Figure 15: Stream evolution model (Cluer and Thorne 2013)

Table 3: Bankfull width measurements

BFW number	Width (feet)	Included in design average?	Location measured *(STA)*	Concurrence notes
US 1	10.0	No	Upstream Reach; existing STA 8+30	Comanagers concurred on 12/17/2021
US 2	5.5	No	Upstream Reach; existing STA 8+53	Comanagers concurred on 12/17/2021
US 3	5.5	No	Upstream Reach; existing STA 8+64	Comanagers concurred on 12/17/2021
US 4	6.5	No	Upstream Reach; existing STA 9+07	Comanagers concurred on 12/17/2021
US 5	7.5	No	Upstream Reach; existing STA 9+22	Comanagers concurred on 12/17/2021
DS 1	7.0	Yes	Downstream Reach; existing STA 2+92	Comanagers concurred on 12/17/2021
DS 2	7.5	Yes	Downstream Reach; existing STA 2+62	Comanagers concurred on 12/17/2021
DS 3	7.0	Yes	Downstream Reach; existing STA 2+47	Comanagers concurred on 12/17/2021
DS 10	8.0	Yes	Reference Reach; existing STA 1+38	Comanagers added on 12/17/2021
DS 11	8.0	Yes	Reference Reach; existing STA 1+20	Comanagers added on 12/17/2021
DS 12	18.0	No	Reference Reach; existing STA 0+99	Comanagers added on 12/17/2021
DS 13	9.0	Yes	Reference Reach; existing STA 0+74	Comanagers added on 12/17/2021
DS 14	7.0	Yes	Reference Reach; existing STA 0+30	Comanagers added on 12/17/2021
Design average	7.6	N/A	N/A	Comanagers agreed on 12/17/2021 on a design average between 7 to 9 feet

US = upstream
DS = downstream

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Figure 16: Typical upstream BFW

Figure 17: Typical downstream BFW

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Figure 18: Typical reference reach BFW

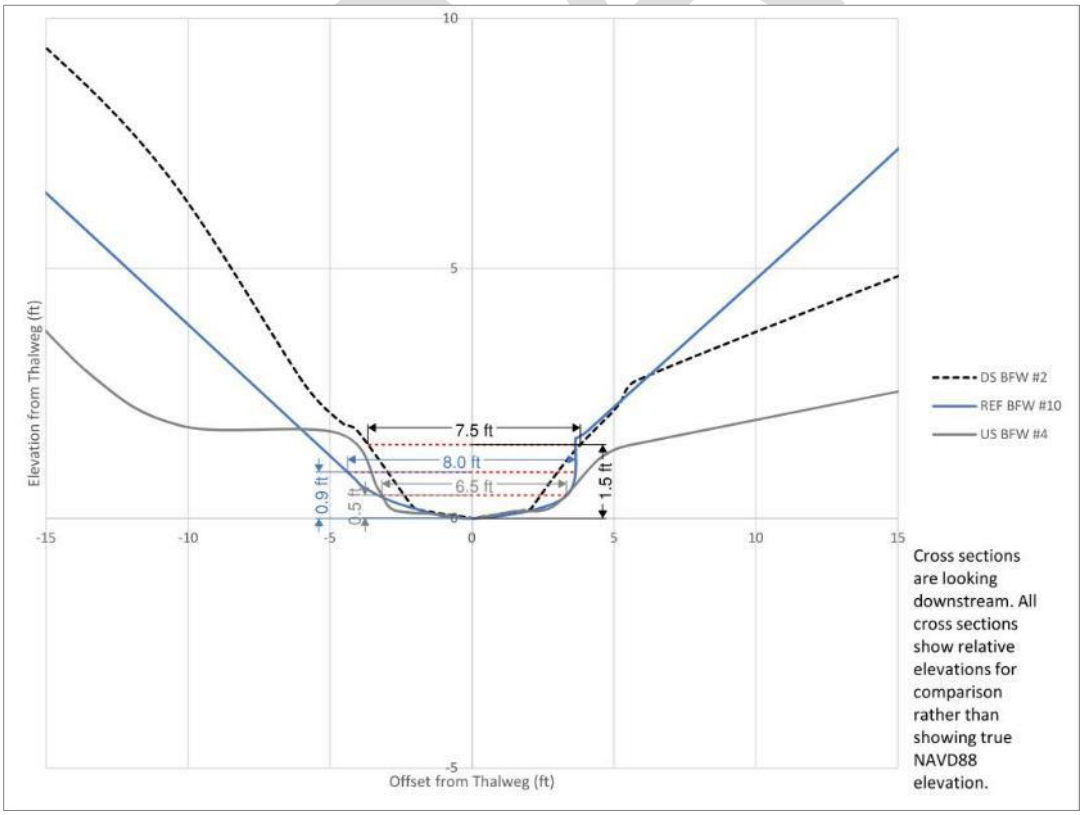

Figure 19: Typical BFW cross sections

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2.7.2.1 Floodplain Utilization Ratio

The FUR is defined as the flood-prone width (FPW) divided by the BFW. A ratio under 3.0 is considered a confined channel and a ratio above 3.0 is considered unconfined. The FUR for this crossing was calculated using the field-measured BFW (as shown in Table 3) and the existing-conditions, 100-year event water surface width as the FPW. Figure 20 shows the locations of the BFW measurements and the FUR calculations.

Seven of the eight downstream cross sections were used to calculate the average FUR. BFW DS 12 was excluded because it was abnormally wide due to two instream LWM pieces. BFW DS 10 to BFW DS 14 are within the reference reach. Upstream sections were not used in FUR calculations because they are not in a reach with a similar slope to the proposed crossing and were not used in design BFW calculations. BFW US 1 to BFW US 3 exhibit large FUR values due to deposition near the crossing and are not characteristic of the natural creek morphology. The average FUR for this crossing is 1.6, indicating that the channel is confined, as shown in Table 4.

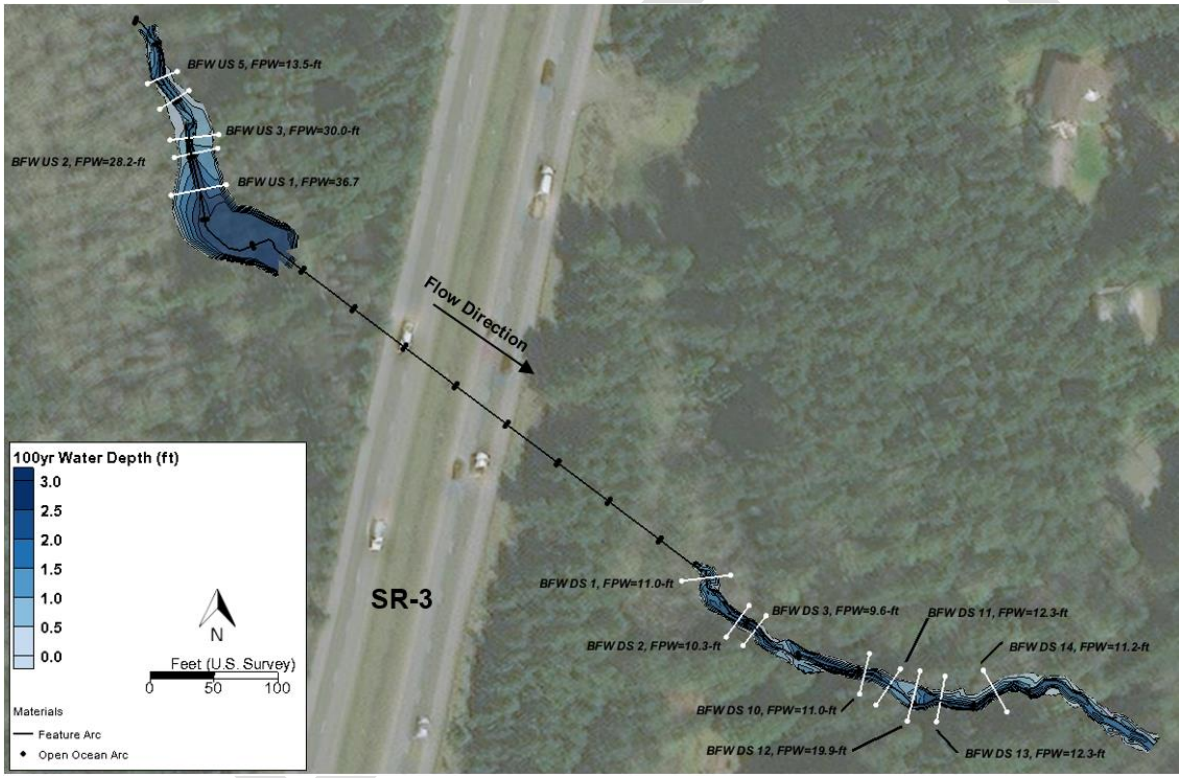

Figure 20: FUR locations

Table 4: FUR determination

Measurement Location	FPW (ft)	FUR	Confined/ Unconfined	Included in average FUR determination
BFW US 1	36.7	3.7	Unconfined	No
BFW US 2	28.2	5.1	Unconfined	No
BFW US 3	30.0	5.5	Unconfined	No
BFW US 4	13.1	1.8	Confined	No
BFW US 5	13.5	1.8	Confined	No
BFW DS 1	15.3	2.2	Confined	Yes
BFW DS 2	10.3	1.4	Confined	Yes
BFW DS 3	9.6	1.4	Confined	Yes
BFW DS 10	11.0	1.4	Confined	Yes
BFW DS 11	12.3	1.5	Confined	Yes
BFW DS 12	19.9	1.2	Confined	No
BFW DS 13	12.3	1.6	Confined	Yes
BFW DS 14	11.2	1.6	Confined	Yes
Average	**11.7**	**1.6**	**Confined**	N/A

2.7.3 Sediment

Upstream and downstream of the crossing, the bed material is typically clast-supported, meaning larger clasts are touching and supporting each other. Interstices between the clasts contain sand and organic debris (Figure 21). Five total pebble counts were conducted, two in the upstream reach, two in the downstream reach, and one in the reference reach (Figure 7).

The grain size distributions of the pebble counts (Figure 22) do not typically reflect the size of the bed material that comprises the steps in step-pools (which were generally less than 12 inches in size), but characterizes the incoming, mobile sediment load. Similarity in the upstream and downstream grain size distributions may indicate sediment continuity (incoming sediment can be transported out) and that the availability of incoming sediment load does not present a design constraint. Due to the small channel width, the two pebble counts in the downstream reach were modified with a sample size of 30 each. All other pebble counts were near the recommended sample size of 100. No boulders were noted in the stream. The average median grain size (D_{50}) is 0.8 inch (Table 5), however there is a significant mode in sand. This sand fraction (10 percent or greater) can enhance the incipient motion of larger clasts in the streambed. Figure 22 presents the sediment size distribution for all pebble counts for the upstream and downstream reaches.

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Table 5: Sediment properties near the project crossing

Particle size	US Pebble Count 1 diameter (in)	US Pebble Count 2 diameter (in)	DS Pebble Count 1 diameter (in)	DS Pebble Count 2 diameter (in)	Ref Reach Pebble Count 1 diameter (in)	Average diameter for design (in)
Included in average?	Yes	Yes	Yes	Yes	Yes	N/A
$\mathbf{D_{16}}$	0.03	0.08	0.03	0.5	0.02	0.13
$\mathbf{D_{50}}$	0.5	0.7	0.8	1.3	0.8	0.8
$\mathbf{D_{84}}$	1.8	2.2	2.2	2.5	2.9	2.3
$\mathbf{D_{95}}$	2.5	3.0	2.8	3.4	4.6	3.3
$\mathbf{D_{100}}$	5.0	5.0	3.6	5.0	7.1	5.1

Figure 21: Typical sediment size distribution

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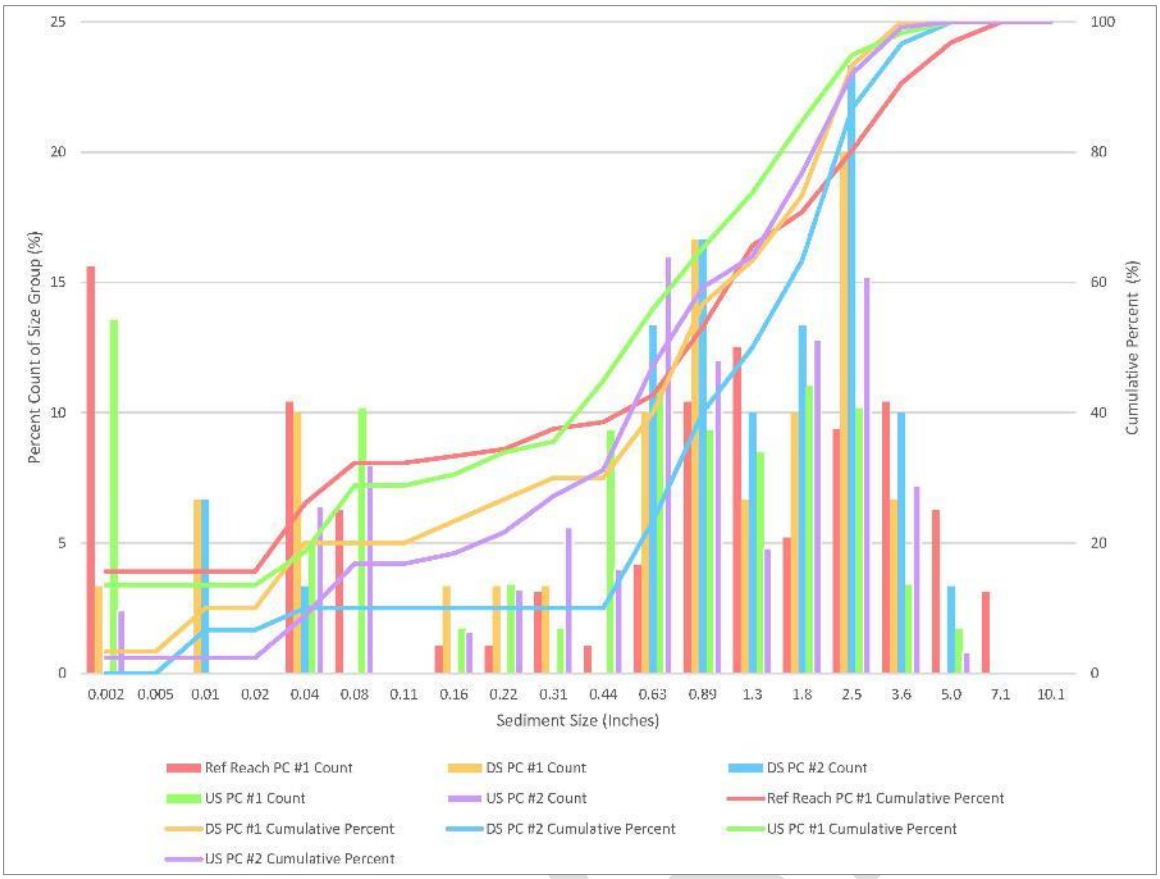

Figure 22: Sediment size distribution

2.7.4 Vertical Channel Stability

The longitudinal profile of the SF Johnson Creek channel (Figure 23) shows a generally straight profile. The profile is not concave-upwards until the last 1,000 feet of the profile, where Johnson Creek enters Liberty Bay. Just upstream of the SR 3 crossing, the profile gradient is flattest (4 percent), but most of the profile gradient is 5 to 7 percent. The steepness of the profile is due to the relief between base level to Johnson Creek (Liberty Bay) and the relatively high, flat-lying and resistant glacial drift that forms most of the watershed. The channel traverses a significant elevation change over a relatively short distance.

Through and downstream of the crossing, the profile actually exhibits a slight convexity, indicating either the presence of resistant material or more material (or load) than can transported. If the convexity is due to the presence of mass-wasting deposits in the channel, the material may represent local, transport-limited conditions. These deposits may be the primary sediment source to the project reach. Glacially-derived sediments in the upper watershed may also contribute load but the low slope of much of the upper watershed limits transport. Sediment supply to the project reach may be mass-wasting deposits in the channel and valley bottom with minor contributions from small tributaries on the south side of the valley. Sediment may also be generated by stream incision, but acute, ongoing incision was not observed. Because the convexity in the profile may represent sediment in storage, potential for downstream aggradation is increased but also offset by the steep gradient of the downstream channel.

The potential for either aggradation or degradation is ultimately a function of the balance, over time, between transport capacity and incoming sediment supply. If sufficient sediment is mobilized at larger, infrequent floods, aggradation of less than 2 feet may occur on the falling limb of the flood event. No evident long-term grade controls were observed either in the field or in the longitudinal profile. For a detailed analysis about degradation and aggradation, see Section 7.2.

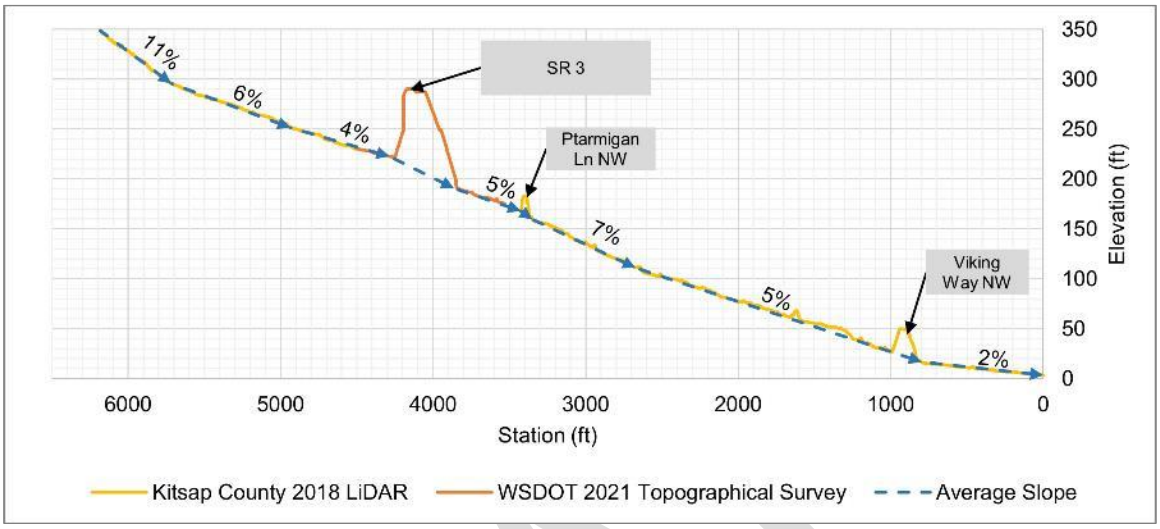

Figure 23: Watershed-scale longitudinal profile

2.7.5 Channel Migration

Upstream and downstream channel sinuosity is low to modest (<1.15), which generally indicates a low risk for channel avulsion and subsequent migration. The greatest risk of channel migration may result if a hydraulically smooth floodplain is constructed adjacent to a steep channel of high roughness. At higher floods, the hydraulically smoother floodplain may be at risk of incision and abandonment of the rougher channel.

In the existing channel, the upstream reach exhibits a significant floodplain, but flow paths in the floodplain are not noticeable. Although backwater is present at the inlet (at higher flows), no obvious, excess sediment deposition was observed either in the channel or on the floodplain. These field observations seem to indicate that transport capacity is commonly adequate to transport the incoming sediment load. This balance attenuates the risk of lateral migration because excess deposition may trigger the development of multiple channel threads. However, if mass-wasting is reactivated, sediment pulses may be introduced to the channel and trigger changes in alignment. In the downstream reach, the steepness and confinement of the channel indicate that the floodplain is infrequently accessed. The steepness of the design channel limits floodplain development (floodplains are depositional features) and migration. Both upstream and downstream reaches appear to be at moderate risk of channel migration. However, if the floodplain is occupied during a high-magnitude, long-duration flood event, risk of channel migration (avulsion) is nontrivial due to the “very high” erodibility rating of the glacial materials (WSDOT 2021b).

3 Hydrology and Peak Flow Estimates

This section describes the SF Johnson Creek watershed delineation, the different methods utilized for peak flow estimation and validation, and predicted climate change impacts to peak flows. Low summer flow conditions are not known and were not evaluated as it is beyond the scope of this preliminary hydraulic design (PHD). Low-flow calculations should be considered to support step height design as part of the final hydraulic design (FHD).

There is no historical flow data available for the tributary to SF Johnson Creek. The nearest flow gage is USGS Gage No. 12054000, located on the Duckabush River near Brinnon, nearly 16 miles west of the SR 3 culvert crossing (the Duckabush River is orders of magnitude larger than SF Johnson Creek, with a drainage area of 66.5 square miles and on the opposite side of Hood Canal). Peak flow estimates were developed using MGSFlood (MGS Software LLC. 2021) and field indicators and validated using the upper limit of the USGS Regression Equations for Region 3 (Mastin et al. 2017).

The SF Johnson Creek watershed boundaries were delineated using 3-foot resolution gridded LiDAR (USGS and Quantum Spatial 2018) and ArcHydro (ESRI n.d.) terrain-processing routines within ArcGIS software. Channel burning routines were not used because available depictions of hydrography[2] are too coarse in resolution to adequately define the tributary to SF Johnson Creek channel. In addition to LiDAR terrain, culvert locations from the WDFW culvert database (WDFW n.d.-b) and utilities from the Kitsap County stormwater dataset (Kitsap County 2018) were utilized to guide watershed boundary delineation (Figure 2). The resulting watershed is approximately 240 acres (0.37 square mile) in size and extends approximately 1 mile west from SR 3, across a shallow valley and Clear Creek Road and partially into Bangor Naval Base. No investigation of stormwater utilities was conducted within the base; therefore, watershed delineations within the base relied on LiDAR terrain. No as-built plans or aerial imagery of surface water storage or other hydrologic facilities were identified within the SF Johnson Creek watershed.

A MGSFlood model was generated because the watershed size (0.37 square mile) is near the lower limit of the USGS Regression Equation valid range (0.08 to 2,605 square miles), the basin's percent impervious area (7 percent) is larger than the recommended standard in which Regression Equations should be used (5 percent) and because MGSFlood incorporates more refined hydrology methods based on land cover and soils. MGSFlood inputs are watershed areas associated with a combination of land cover and soil type. Land cover was estimated based on National Land Cover Database (MRLC 2019a; Section 2.2), and soil type was estimated based on a combination of subsurface geology (NRCS USDA 2021; Section 2.3) and Soil Survey Geographic Database (SSURGO) (NRCS USDA 2021; Section 2.3). Consistent with MGSFlood guidance (MGS Software LLC. 2021), soils identified by SSURGO as hydrologic soil Group B used underlying geology to assign outwash and till soil designations. Inputs for MGSFlood and the model results using a 15-minute time step are provided in Appendix N.

[2] The National Hydrography Dataset (USFS 2019) and the Washington State Department of Ecology's (n.d.) stream dataset.

USGS Regression Equation inputs include watershed area and mean annual precipitation. A mean annual precipitation of 41.3 inches was determined based on the 30-year climate normal (PRISM Climate Group, Oregon State University 2020). The USGS Regression Equation also provides lower and upper prediction intervals (PI_l and PI_u respectively), acknowledging the uncertainty associated with this method. The upper limit of the USGS Regression Equation for Region 3 was used for validation because the basin's percent impervious area (7 percent) is larger than the recommended standard in which regression equations should be used (5 percent). Regression equation results are provided in Appendix N.

Bankfull measurements collected during the December 1, 2021, site visit were utilized as field indicators to validate the peak flow estimates. Hydraulic model simulations were performed iteratively to determine bankfull flow relative to the measured BFW. This bankfull flow is typically considered the 1.2- to 1.5-year event and is approximated for the hydrologic analysis as the 2-year flow (Q_2). The hydraulic model simulations resulted in an estimated Q_2 of 21 cubic feet per second (cfs).

MGSFlood results are within the 90 percent confidence level prediction interval of the USGS Regression Equation estimates. When compared to the USGS Regression Equation central estimate (Q_u), MGSFlood is higher indicating the peak flows obtained by the regression equations underpredict the MGSFlood values. Both MGSFlood and the upper limit of the USGS Regression Equations underpredict the Q_2 derived from field indicators. The final selected method of peak flow development relied on the field indicated Q_2, to allow for a conservative design. To meet the field-condition Q_2, the MGSFlood results for all mean recurrence intervals (MRI) were scaled by a factor of +38 percent. Peak flow estimate results, including baseline and scaled MGSFlood results, are provided in Table 6.

WSDOT recognizes climate resilience as a component of the integrity of its structures, and approaches the design of bridges and buried structures through a risk-based assessment beyond the design criteria. The largest risk to bridges and buried structures will come from increases in flow and/or sea level rise. The goal of fish passage projects is to maintain natural channel processes through the life of the structure and to maintain passability for all expected life stages and species in a system.

WSDOT evaluates crossings using the mean percent change in 100-year flood flows from WDFW's (n.d.-b) Future Projections for Climate-Adapted Culvert Design program. All sites consider the projected 2080 percent increase throughout the design of the structure. Appendix G contains the projected increase information for the project site. The selected design flow for the crossing is 85 cfs at the 100-year storm event. The projected increase for the 2080, 100-year flow is 62.2 percent, yielding a projected 2080, 100-year flow of 138 cfs (selected method).

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Table 6: Peak flows for SF Johnson Creek at SR 3

Mean Recurrence Interval	Selected Method - MGSFlood Scaled by 1.38 (cfs)	MGSFlood (cfs)	Check Method - USGS Regression Equation (Region 3) ([PII], Qu, [Plu] in cfs)
2	21[a]	15	(4) 8 (17)
10	44	32	(8) 17 (34)
25	60	43	(10) 21 (46)
50	79	57	(11) 24 (54)
100	85	62	(12) 28 (64)
500	100	72	(15) 36 (90)
Projected 2080, 100	(138; +62.2%)	(101; +62.2%)	([20] 45 [104]; +62.2%)

a. Two-year flow developed from hydraulic model and field estimated BFW (field indicator).

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4 Water Crossing Design

This section describes the water crossing design developed for SR 3 MP 50.85 SF Johnson Creek, including channel design, minimum hydraulic opening, and streambed design.

4.1 Channel Design

This section describes the water crossing design developed for SR 3 MP 50.85 SF Johnson Creek. The proposed design utilizes two typical cross sections, one for the pool sections and one for the cascade and step sections, that are implemented over 520 feet of channel grading and described further in Section 4.1.2. Sections 4.1.3 and 4.1.1 provide additional information on the proposed alignment and gradient, respectively, wherein we propose a general gradient trend with local variability to capture the step-pool system.

A step-pool design to navigate the moderately high gradient through a passing structure can be an effective means of passage with consideration given to minimum pool depth and length. Since this passage structure is exceptionally long, consideration should be given to intermittent “resting pools” within the structure that are a slightly longer length and depth to give fish a mid-way “rest stop” during migration through the 400-foot-long culvert (see Section 4.3.2.3. for further discussion). During higher flows, fish may be swept through the culvert and over rock features. The design should ensure that only rounded boulders are used to reduce abrasion and facilitate passage of lamprey species (if present).

The design should also consider resting/holding pools with significant cover upstream and downstream of the culvert entrance where fish can rest or hold before and after traversing the length of the culvert. Significant cover should be provided within these pools, in the form of LWM and dense overhanging vegetation, to prevent predation of juvenile fish when they transition to and from the culvert (see Section 4.3.2. for further discussion). Salmonids can be wary of entering an area with a sharp light/dark transition (such as a culvert) and may hesitate at the entrance on both ends, making them vulnerable to predation at the mouth and entrance of the culvert. Similarly, fish emerging from the culvert on the upstream end may have exhausted energy stores during upstream migration through the step-pool structures and may benefit from a resting area (pool) with slower velocities upon emergence from the culvert.

Longer culverts may provide lower foraging opportunities within the structure itself as salmonids rely on a phototropic food chain where their prey base (invertebrates) are reliant on light-dependent algae and other aquatic plants as well as decaying organic matter. The final design may consider foraging opportunities in the downstream end by daylighting 100 feet of proposed crossing rather than walls.

Typically, fish passage becomes limited even in natural streambed channels during high flows, initially for juvenile fish and eventually halting migration for even adult fish. During exceptionally high flows (20-year events and above, though this greatly depends on the nature of the channel, available refuge habitat, slope, etc.) all fish will tend to take refuge to conserve energy, entering newly watered side channels, deep holding pools, protected undercut banks, and floodplains.

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4.1.1 Channel Gradient

The proposed grading (520 total linear feet) was selected to limit disturbance of the riparian conditions upstream and downstream, to reduce impacts to the site on either side of the culvert, and is placed at the same location as the existing crossing to minimize impacts to the steep valley walls and surrounding homeowners. The grading begins approximately 90 feet upstream of the existing crossing to tie-in line to the existing thalweg beyond the high-flow depositional area near the culvert. Similarly, the downstream grading ends at the end of the steep riprap section placed to stabilize the channel at the existing culvert's outlet. Both of the tie-in points were selected with comanagers during the December 17 site visit (see Appendix B for field notes).

The stream gradient immediately upstream of the proposed grading has a slope ranging from 4.4 to 2.7 percent as you travel upstream (see Appendix D, Sheet CP1). This slope is slightly lower than the watershed trends and may likely be the result of long-term aggradation at the culvert inlet or other anthropogenic impacts. The WCDG (Barnard et al. 2013) recommends that the proposed crossing bed gradient be within 25 percent of the existing stream gradient upstream of the crossing. The proposed grading begins with a gradient of 4.1 percent, giving a slope ratio of 0.93 when compared to the existing upstream gradient of 4.5 percent. However, after 70 feet, the proposed grading transitions to an overall gradient of 7.3 percent, giving a slope ratio of 1.78. The channel then transitions to the existing downstream gradient of 4.9 percent, giving a slope ratio of 0.67 . While the slope ratio is not within the recommended 25 percent, the gradient changing from 4 to 7 percent is what can naturally be seen at the project scale, as noted in Appendix D, Sheet CP1. Additionally, when compared to the reference reach slope of 6.6 percent, the proposed gradient of 7.3 percent is within the recommended 25 percent comparison range. Figure 23 shows the slope of the watershed profile varies from 2 to 11 percent, with an overall slope of roughly 5 to 7 percent. Downstream of the crossing (beyond riprap), the stream gradient varies from 2.4 to 7.8 percent (Appendix D, Sheet CP1), which similarly matches the proposed grading (see Appendix D, Sheet CP2 for more details). Because upstream adjacent channel reaches are steeper than the proposed 4 percent subreach, long-term degradation is possible upstream up to 3 feet (see Section 7.2 for more details).

4.1.2 Channel Planform and Shape

As mentioned in Section 2.7.1, the reference reach identified and considered in developing the preliminary design is located approximately 220 feet downstream of the SR 3 crossing and extends for another 50 feet downstream. Per the WCDG (Barnard et al. 2013) the proposed planform and shape of the proposed design mimics the reference reach with adjustments based on engineering and geomorphic judgements. The proposed cascade geometry includes a 7-foot BFW and a 0.9-foot bankfull depth with floodplain benches on both sides that mimic the downstream reference reach (Figure 24).

The channel bottom is sloped at 10:1, for a total of 2 feet, to concentrate lower flows, while the banks are sloped at 3:1 for 2.5 feet to promote fringe habitat. The floodplain slopes at approximately 10:1, allowing for more frequent inundation at higher flood flows for 4.0 feet on each side, matching reference reach valley widths, and then transitioning to 3:1 to catch existing ground. The 3:1 side slopes allow for the growth of increased vegetation varieties. At this stage in design, the typical cascade cross section at the 4 percent slope is the same as the typical

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cascade cross section at the 7 percent slope, this may be refined at further stages of design. The proposed step geometry in the design is the same as the cascade cross section and includes complexity features, such as LWM and boulders. Section 4.3.2 provides additional information on step design, including complexity features.

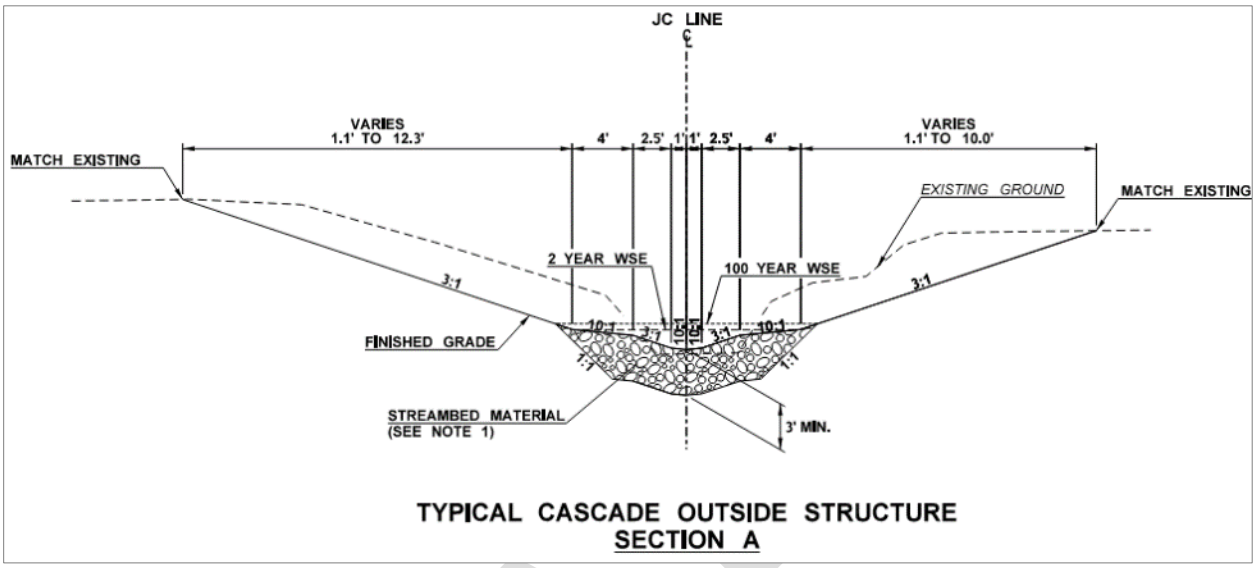

Figure 24: Proposed cascade cross section

The proposed pool geometry is similar to the cascade but has a 10-foot BFW and a deeper thalweg of 1.4-foot bankfull depth (Figure 25). The channel bottom is sloped at 10:1, for a total of 2 feet, to concentrate lower flows, while the banks are sloped at 3:1 for 4 feet. The floodplain slopes at approximately 5:1, allowing for more frequent inundation at higher flood flows for 2.5 feet on each side, matching reference reach valley widths, and then transitioning to a 3:1 to catch existing ground. The 3:1 side slopes allow for the growth of increased vegetation varieties. Within the crossing, the floodplain is at a minimum of 4.5 feet between the main channel and the structure wall and varies in length to a maximum of 10.5 feet to allow for LWM to be placed within the crossing.

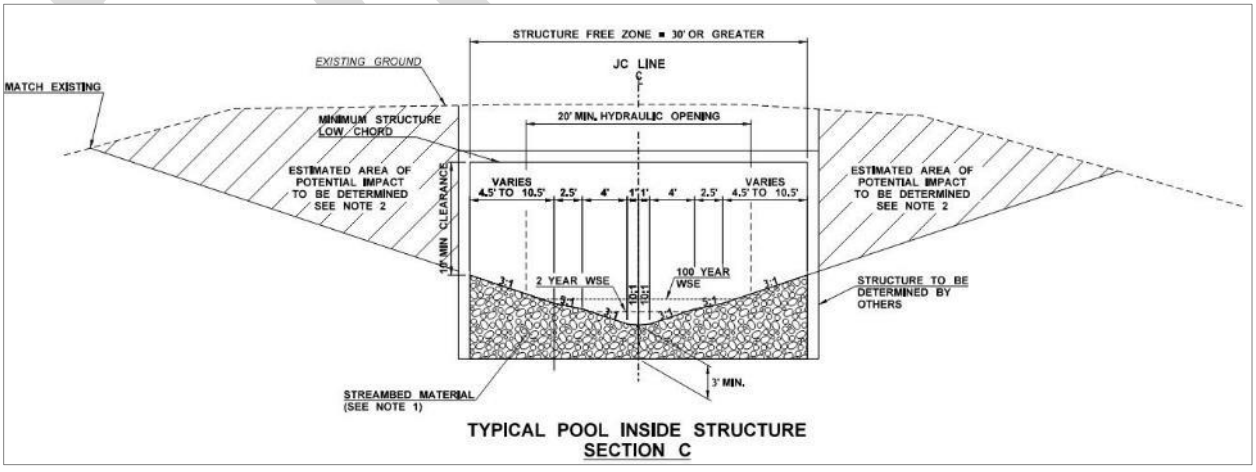

Figure 25: Design cross section

When outside of the crossing footprint, the graded surface slopes at 3:1 from the floodplain edge to catch the existing ground (Figure 26). Appendix D provides existing and proposed channel cross sections and planforms. As noted in Section 5 and shown in Appendix H, the proposed channel will provide similar hydraulic trends (particularly velocity and shear stresses) at several hundred feet upstream of the crossing as well as the reference reach and therefore should provide continuous sediment transport. The 2-year event flow, which is interchangeable with the bankfull event for this PHD (see Section 3), will begin to activate the floodplain benches. Furthermore, the 100-year velocity through the crossing is comparable to the upstream velocity. The main channel is not anticipated to change too much as the 2080 percent change in BFW is 8 percent, per WDFW's Future Projections for Climate-Adapted Culvert Design program (n.d.-b; Appendix G). However, as noted in Section 3 and shown in Appendix G, the projected increase for the 2080, 100-year flow is 62.2 percent. Due to the dramatic change in 100-year flows, further analysis into the final cross section and floodplain material will be done in the FHD.

A low-flow channel will be added in later project stages that connect habitat features together so that the project is not a low-flow barrier. The low-flow channel will be as directed by the engineer in the field. Additional information on the size of streambed material is in Section 4.3.1 and should be considered in concert with the low-flow channel geometry.

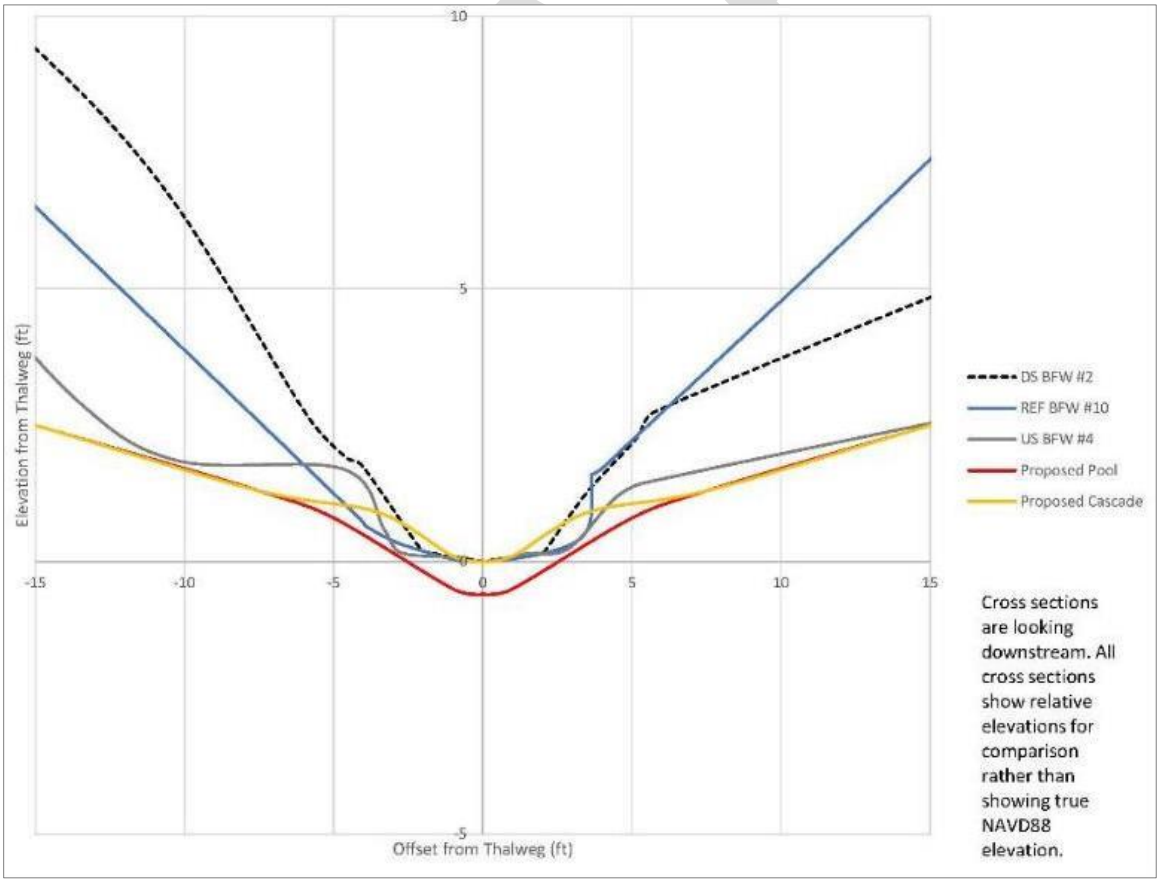

Figure 26: Proposed cross sections superimposed with existing survey cross sections

4.1.3 Channel Alignment

As noted in Section 4.1.1, the proposed grading is 520 total linear feet. The proposed channel upstream of the new crossing includes several meander bends with a 24-foot centerline radius of curvature and a sinuosity of 1.06. For a BFW of 7 feet, this yields a radius of curvature:width (Rc:w) ratio of 3.4. A larger Rc:w ratio is desirable where channel migration may be constrained by crossing structures. Channels with a Rc:w ratio of 2 to 3 have been shown to minimize energy loss around a bend such that more energy is available for erosion and subsequent migration. Migration rates have been shown to significantly decrease when the Rc:w ratio is greater than 3 (Nanson and Hickin 1986). Cohesion and bank material size also drive channel migration, but the tendency toward migration can be modulated using the Rc:w ratio. As the proposed channel transitions into a steeper gradient, and the step-pool system through the new crossing, the alignment becomes less sinuous (1.03) than the regraded upstream reach but matches what was seen in the reference reach, as noted in Section 2.7.2. Within the steeper proposed reach, sinuosity is created by unpredictable interactions with LWM pieces such that alignment cannot be prescribed by empirical relations like Rc:w ratio. Appendix D provides the proposed alignment and grading.

4.2 Minimum Hydraulic Opening

The minimum hydraulic opening is defined horizontally by the hydraulic width, and the total height is determined by vertical clearance and scour elevation. This section describes the minimum hydraulic width and vertical clearance; for discussion on the scour elevation see Section 7. Figure 27 illustrates the minimum hydraulic opening, hydraulic width, freeboard, and maintenance clearance terminology.

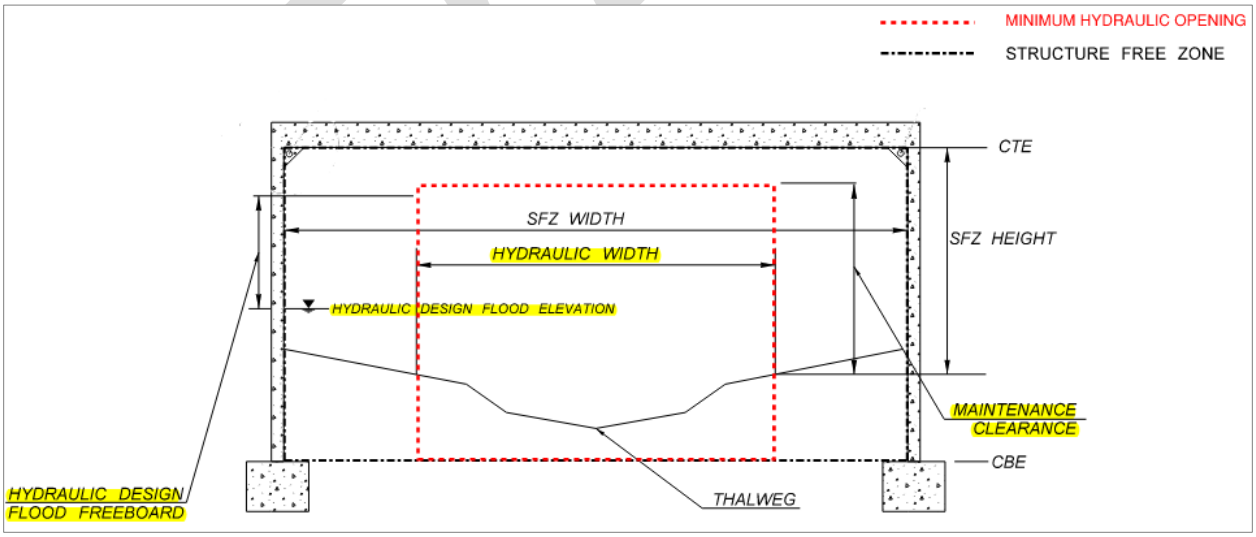

Figure 27: Minimum hydraulic opening illustration

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4.2.1 Design Methodology

The proposed fish passage design was developed using WDFW's WCDG (Barnard et al. 2013) and WSDOT's Hydraulics Manual (2022). WDFW's WCDG contains methodology for five different types of crossings: No-Slope Culverts, Stream Simulation Culverts, Bridges, Temporary Culverts or Bridges, and Hydraulic Design Fishways. The permanent federal injunction allows for the use of the stream simulation method and the bridge design method unless unsurmountable circumstances exist onsite (constraints of landownerships or infrastructure for example). According to the WCDG, a bridge should be considered for a site if any of the following should be met: the FUR is less than 3.0, the BFW is greater than 15 feet, the channel appears unstable, the slope ratio exceeds 1.25 between the existing channel and the new channel, the channel is debris prone, or the culvert is very long (beyond 10:1 length-to-width ratio).

Using the guidance in the WCDG (Barnard et al. 2013) and the *Hydraulics Manual* (WSDOT 2022), the confined bridge methodology through the crossing was determined to be the most appropriate. As noted in Section 2.7.2, the typical BFW is not greater than 15 feet. Sections 2.7.4 and 2.7.5 note that the existing channel appears to be stable laterally and vertically. Additionally, the FUR is less than 3.0 (Section 2.7.2.1), the proposed crossing exceeds the 10:1 length-to-width ratio (Section 4.2.2), and the slope ratio exceeds 1.25 through the new crossing (Section 4.1.1). Section 4.1.1 notes that the channel has low channel migration vertically and horizontally. The design allows for increases in flow from climate change by providing additional width beyond the minimum and floodplains that can readily be active (Section 4.1.2)

4.2.2 Hydraulic Width

The starting point for the minimum hydraulic width determination of all WSDOT crossings is Equation 3.2 of the WCDG, rounded up to the nearest whole foot. For this crossing, with a 7-foot BFW, a minimum hydraulic width of 11 feet was determined to be the minimum starting point. Since the culvert is very long (beyond 10:1 length-to-width ratio), WSDOT requires a 30 percent increase in the hydraulic width, resulting in a minimum hydraulic width of 15 feet. A subsequent iteration of the minimum hydraulic opening found that a 14- to 20-foot width is needed to accommodate future channel sinuosity through the crossing and allow for natural processes to mimic the reference reach in the typical run and pool cross sections and the Q100 span. The risk of lateral migration is moderate, as described in Section 7.1; however, the risk could be reduced with the LWM structures placed upstream of the crossing and with the widened minimum hydraulic opening. Additionally, as discussed in Section 2.5, the ideal minimum hydraulic opening for habitat connectivity is 20 feet.

Ultimately, the structure-free zone is driven by the installation of LWM within the crossing, described in further detail in Section 4.3.2. Consideration of sufficient width beyond the length of wood, and including a factor of safety, influenced the structure-free zone to be 30 feet wide or greater. The 30-foot or greater width allows for a minimum of 4.5 feet between the proposed crossing wall and the meandering top of the proposed banks, reducing the risk of entrainment against the walls and allowing space for the proposed LWM to be installed. Installation of LWM within the crossing requires additional structure width to partially bury the wood beyond the 20 feet required for the channel; the structure-free zone of 30 feet or greater may need to be

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increased further in future design due to the restoration, complexity features, and stability of the proposed design. Additionally, the 30 foot or greater structure-free zone falls within the range of the measured valley width and will accommodate peak flows and maintain an appropriate velocity ratio. While velocities will be high when compared to Table 1 in Appendix B of the WCDG (Barnard et al. 2013), which indicates flow velocities appropriate for adult Chinook, coho, sockeye, and steelhead migration, channel complexity features will create pockets of slower moving water to allow for aquatic resting areas. Table 7 shows the minimum hydraulic opening required for each metric compared to the chosen minimum hydraulic opening. Section 4.2.3 provides the associated vertical clearance requirements, and Section 4.2.4 provides the hydraulic length.

Table 7: Minimum hydraulic opening summary

Metric	Minimum Hydraulic Opening (ft)
Equation 3.2 of the WCDG	11
Length:Width Ratio	15
Q100 Span	14
Meander Width	20
Valley Width	20 to 40
Habitat Connectivity	20
Large Woody Material in Crossing	30
Chosen Minimum Hydraulic Opening	**20**
Chosen Structure Free Zone	**30**

Based on the factors described above, a minimum hydraulic width of 20 feet with a structure-free zone of 30 feet or greater was determined necessary for allowing natural processes to occur under current flow conditions. The design team evaluated the projected 2080, 100-year flow event. Table 8 compares the main channel average velocities of the 100-year and projected 2080, 100-year events.

Table 8: Velocity comparison for 30-foot structure-free zone

Location	100-year velocity (fps)	Projected 2080, 100-year velocity (fps)
Reference reach (BFW 13, STA 0+30)	6.5	6.9
Upstream of structure (STA 7+95.18)	4.5	4.8
Through structure (STA 7+00)	6.2	6.9
Downstream of structure (STA 2+47)	6.4	7.1

fps = feet per second

No size increase was determined to be necessary to accommodate climate change. For detailed hydraulic results see Section 5.4.

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4.2.3 Vertical Clearance

The vertical clearance under a structure is made up of two considerations: freeboard and maintenance clearance. Both are discussed below, and results are summarized in Table 9.

The minimum required freeboard at the project location, based on BFW, is 1 foot above the 100-year WSE (Barnard et al. 2013; WSDOT 2022). The WSDOT *Hydraulics Manual* requires 3 feet of freeboard for all structures greater than 20 feet and on all bridge structures unless otherwise approved by HQ Hydraulics (WSDOT 2022).

WSDOT is incorporating climate resilience in freeboard, where practicable, and has evaluated freeboard at both the 100-year WSE and the projected 2080, 100-year WSE. The WSE is projected to increase by 0.3 foot for the projected 2080, 100-year flow rate. The minimum required freeboard at this site will be applied above the projected 2080, 100-year WSE to accommodate climate resilience.

The second vertical clearance consideration is maintenance clearance. WSDOT HQ Hydraulics determines a required maintenance clearance if a height is required to maintain habitat elements, such as boulders or LWM. If there are no habitat elements requiring maintenance clearance to maintain, the maintenance clearance is only a recommendation by WSDOT HQ Hydraulics, and the region determines the maintenance clearance required.

The channel complexity features in Section 4.3.2 include LWM habitat features within the structure that may need to be maintained. Therefore, a maintenance clearance of 10 feet to allow for machinery to access and operate under the structure is required. Maintenance clearance is measured from the highest streambed ground elevation within the horizontal limits of the minimum hydraulic width.

Table 9: Vertical clearance summary

Parameter	Downstream face of structure	Upstream face of structure
Station	03+06.1	07+03.1
Thalweg elevation (ft)	190.1	219.6
Highest streambed ground elevation within hydraulic width (ft)	194.0	223.5
100-year WSE (ft)	191.7	221.4
2080, 100-year WSE (ft)	192.0	221.7
Required freeboard (ft)	3	3
Required maintenance clearance (ft)	10	10
Required minimum low chord, 100-year WSE + freeboard (ft)	194.7	224.4
Required minimum low chord, 2080, 100-year WSE + freeboard (ft)	195.0	224.7
Required minimum low chord, highest streambed ground elevation within hydraulic width + maintenance clearance (ft)	204.0	233.5
Required minimum low chord (ft)	**204.0**	**233.5**

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As discussed in Section 2.5, the habitat connectivity team met with Jacobs on July 26, 2022, to discuss wildlife connectivity at this site. The habitat connectivity team noted that deer are the anticipated design species for this site, where the target openness ratio is 2.0. The openness ratio of a site is equal to the width of the cross times the height of the crossing divided by the length of the crossing. With a length of nearly 400 feet and a structure-free zone of 30 feet or greater, to get an openness ratio of 2.0, the height of the cross should be minimum of 27 feet. Due to the deep roadway fill, the target openness ratio can likely be met; however, this value was not incorporated into this phase of the PHD and will be look into further once a Wildlife Connectivity Memorandum is received.

4.2.3.1 Past Maintenance Records

As discussed in Section 2.1, WSDOT Area 3 Maintenance was contacted to determine whether there are ongoing maintenance problems at the existing structure because of LWM racking at the inlet or sedimentation. The maintenance representative indicated that there was no maintenance history at this crossing.

4.2.3.2 Wood and Sediment Supply

The SF Johnson Creek watershed is largely forested and open space, with little development. This land cover enables wood recruitment from hillslopes and the riparian corridor to the channel. The channel is relatively narrow in width, which also limits wood recruitment as larger pieces of LWM tend to span the channel. Nevertheless, good potential for wood recruitment and supply is present in the channel and forms many of the observed step-pools. Based on field observations, most LWM is not transportable due to the size (average 20-foot length and 1- to 2-foot DBH) of the LWM relative to the channel width. Transportable LWM tends to be small pieces, at least one-third the width of the channel. Larger pieces that enter the channel tend to form steps or other obstructions. Additional information on LWM in the system is discussion Section 2.6.4.

Sediment supply to the project reach is abundant, but it is unknown how much of the sediment is available at small, frequently recurring flows versus high-magnitude, low-frequency floods. Extensive mass-wasting deposits are mapped at the project reach (Figure 5, Section 2.3). However, it is unclear when these sediments are transportable and, for the most part, may be in storage rather than significant sediment sources. However, they may become a source at high-magnitude floods. Field observations do not point to ongoing, excess aggradation. Consequently, aggradation appears to not be a current problem, but the potential exists for significant aggradation (further discussion on Section 2.7.3 and Section 7.2). This potential cannot be quantified without detailed field mapping.

4.2.4 Hydraulic Length

Currently, the proposed design shows a hydraulic length of 400 feet and a vertical clearance of 10 feet. As discussed in Section 4.2.2, the minimum hydraulic opening was increased by the WSDOT-required 30 percent and then further increased to accommodate LWM placement inside the crossing. Therefore, no additional increase in width is necessary to compensate for the crossing length. As design progresses, a shorter crossing would not be expected to result in a narrowing of the structure due to the LWM placement. At this time, a bottomless, three-sided

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structure has been recommended, and effort should be made to minimize the proposed crossing hydraulic length to the extent practicable. These options will be looked at by a geotechnical and structural engineer at the FHD.

4.2.5 Future Corridor Plans

Future corridor plans were requested from the Project Engineer's Office by the design team. At the time of preparing this PHD, no corridor plans (if they exist) were provided

4.2.6 Structure Type

WSDOT HQ Hydraulics recommends using a bottomless, three-sided structure. The layout and verification of structure type will be looked at by a geotechnical and structural engineer at the FHD.

4.3 Streambed Design

This section describes the streambed design developed for SR 3 MP 50.85 SF Johnson Creek. As mentioned in Section 2.7.1, during the reference reach and BFW concurrence site visit with WDFW and the Tribes on December 17, 2021, the attendees agreed to a "replace in kind" approach with a 7 percent crossing with step-pools in the crossing, which influenced the proposed streambed material.

4.3.1 Bed Material

The bed stability approach typically used for the streambed aggregate material (SBM) design of PHDs was deemed inappropriate for this crossing as the slope of the proposed design is greater than 5 percent. After discussion with WSDOT HQ, the preferred calculation for SBM design at slopes greater than 5 percent is the Bathurst (1987) calculation. This method uses an empirical SBM equation to determine the D_{84} (the particle size that is larger than 84 percent of the material). Hydraulic values, such as the 100-year width, active channel top width, 100-year design flow, and channel slope, were used as inputs to the incipient motion equation. The D_{84} is the basis for the gradation of the SBM in the chosen location. A gradation was determined using the sizing relationships per the WCDG (Barnard et al. 2013). As mentioned in Section 2.7.3, streambed material upstream and downstream of the crossing is typically clast-supported, meaning larger clasts are touching and supporting each other. Interstices between the clasts contain sand and organic debris. Using the approach above, specifically using the Bathurst (1987) equations, the suggested SBM has a D_{100} of 29 inches, which is nearly four times larger than the existing material, as outlined in Table 10.

Due to the large discrepancy between the existing material and material outlined in the Bathurst equations, the design team also calculated the gradation using the typical Modified Critical Shear Stress Design to size the material between the steps and the steps themselves. This method uses empirical SBM stability equations to determine bed material incipient motion and selects the D_{50} or D_{84} (the particle size that is larger than 50 percent or 84 percent, respectively, of the nearby material) mobilized at a particular design storm event to achieve stability per the WCDG (Barnard et al. 2013). The calculations present the calculated gradation based on the Modified Critical Shear Stress equations, the natural gradation based on natural distribution ratios, the results of the Fuller Thompson analysis (Barnard et al. 2013), and the average

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pebble counts for the project location. After performing hydraulic and substrate mobility calculations using various methods, a single D_{84} is selected. The D_{84} is the basis for the gradation of the SBM in the chosen location. Then a specific WSDOT standard gradation (WSDOT 2022) is selected that most closely matches the final aggregate size.

Results from the proposed 100-year and bankfull flood events were extracted from the proposed two-dimensional (2D) hydraulic model. Maximum hydraulic values, such as flow area, critical depth, velocity, and hydraulic radius, were used as inputs to the incipient motion equations. As noted previously, this methodology is not appropriate as the sole calculation of streambed material for proposed designs with slopes greater than 5 percent. However, due to habitat complexity features in the crossing (discussed in further detail in Section 4.3.2), the design team is more comfortable with less rigid material than that calculated by the Bathurst equation.

Using the approach above (specifically using the Modified Critical Shear Stress design methodology), the suggested SBM for the typical cascade is 80 percent WSDOT 12-inch streambed cobbles with 20 percent WSDOT standard streambed sediment. The D_{50} of the calculated streambed material remains stable up to and through the 2-year event, meanwhile the D_{84} of the calculated streambed material remains stable up to and through the 100-year event. At flow events higher than the 2-year event, it is anticipated that transported bed material will then be replaced from the stored sediment upstream of the crossing. The initial mobility of the streambed allows for the channel to naturally adjust over time. This means the channel widths will begin to increase while channel depths begin to decrease; these changes will result in a decrease in shear stresses and therefore less mobile streambed material. As noted in Section 2.7.3, boulders were not observed in the stream; however, boulders are included as part of the proposed habitat complexity features for stability of the steps. The suggested SBM for the typical step is one-man to two-man boulders. The D_{50}, D_{84}, and D_{100} of the proposed boulders for the steps remains stable up to and through the 100-year event.

Table 10 summarizes the observed grain size distribution versus the proposed grain size distribution as calculated from the Bathurst equation and Modified Critical Shear Stress calculations. The SBM is suggested to be a minimum of 3 feet due to the potential depth of degradation, as further described in Section 7.2.

Appendix C contains all streambed aggregate mix calculations. The design team recommends that in future design phases, other methods of SBM calculations that consider the effect of sand should be considered and refined for the main channel cascade, boulder sizing of the steps, and the floodplain (to avoid the creek migrating to lower roughness or less stable features given the width of the crossing). The design team suggests that the material upstream, downstream, and through the crossing be placed in lifts and washed with fines to fill in void space- these lifts will be placed at the discretion of the engineer in the field. Additionally, while larger boulders are suggested to be placed at the steps with LWM, the material on which the boulders are placed and the streambed material size from the steps into the pools needs to be refined. All these items should be considered further in the FHD, as the reference reach material if placed without compaction is predicted to move too readily compared to how cohesive the banks appeared in the field. Finally, it should be noted that the streambed aggregate mix calculations follow WSDOT's guidance and use the results of the historic 100-year MRI, rather than the 2080, 100-year MRI, which is a 62 percent increase in hydrology, as mentioned in Section 3.

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Sizing the streambed aggregate mix based on the future conditions should be considered in the final design. As mentioned in Sections 2.4 and 2.6.3, the existing stream width, depth, gradient, and substrate is suitable for rearing, migration, and spawning of resident and sea-run cutthroat trout and may be suitable for migration and spawning of anadromous salmon.

Table 10: Comparison of observed and proposed streambed material

Sediment size	Observed diameter for reference reach (in)	Bathurst Proposed diameter (in)	Modified Critical Shear Stress Proposed diameter-Cascade (in)[a]	Modified Critical Shear Stress Proposed diameter-Step (in)[a]
D_{16}	0.02	1.4	**0.8**	**3.9**
D_{50}	0.8	4.6	**3.7**	**14.2**
D_{84}	2.9	11.6	**10.0**	**17.0**
D_{100}	7.1	29.0	**12.0**	**18.0**

a. Selected material.

4.3.2 Channel Complexity

This section describes the channel complexity of the streambed design developed for SR 3 MP 50.85 SF Johnson Creek.

4.3.2.1 Design Concept

Complexity in the crossing and regraded reach will be provided by a slightly sinuous planform, LWM structures placed upstream, within, and downstream of the crossing. The LWM structures are placed to engage with the channel at low-flow up to high-flow events.

LWM should be designed and installed in portions of SF Johnson Creek according to WSDOT (2022) and Fox and Bolton (2007). The LWM should meet and exceed the sizing and characteristics of the reference reach by providing habitat, geomorphic function, sediment storage, bank stability, and hydraulic roughness. As mentioned in Section 2.6.4, existing instream LWM is a mix of legacy coniferous wood and more recent deciduous material. There is a greater amount of LWM in the upstream reach than the downstream reach. Due to the location and small size of the stream, the site does not likely see recreational use for swimming or boating. Potential current and future use for fishing may occur, thus the LWM would be low impact to the recreational user.

The proposed design for the LWM (Figure 28 and Figure 29) shows the proposed 96 pieces of wood to be placed within the 520-foot graded channel, of which 400 feet are within the proposed structure, as noted in Section 4.2.4. LWM is recommended to be placed under SR 3 to act as steps through the length of the crossing. As of this time, the LWM design is conceptual and will need to be field verified in the FHD. The assumed proposed design meets and exceeds the 75th percentile of the number of key pieces and total number of pieces as directed by the metrics provided by Fox and Bolton. However, due to the small size of SF Johnson Creek, the proposed design does not meet the 75th percentile but does meet the 50th percentile of the total volume suggested by Fox and Bolton (2007). LWM larger than suggested would likely impede flow through the project area and was not deemed likely to fall into this size of stream. Table 11 lists Fox and Bolton targets and the proposed LWM design values. Appendix F provides the LWM calculations.

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Table 11: Assumed Project Reach LWM Loading

LWM Loading Component	Design Criteria (75th Percentile) [a]	Design Criteria (50th Percentile) [a]	Proposed Design
Total pieces (quantity)	60	46	96
Total volume (cubic yards)	205.3	105.7	106.0
Key pieces (quantity)	17	10	17

a. Calculated based on Fox and Bolton (2007) metrics using a project reach length of 520 feet and a BFW of 7 feet.

The types of LWM structures are as follows:

Type 1: These LWM structures are placed within the proposed crossing at every step in the step-pool system and consists of two logs in sequence (assumed log type length and diameter at midpoint are shown in Appendix F). These structures are to be partially buried and are anticipated to remain stable up to and through the 25-year flow event; however, they will be allowed to be mobile at the 100-year flow event to mimic the evolution of the stream and to not have a hardened step-pool system within the structure. Additionally, these structures are laterally and vertically varied to allow for variable flow depths at all hydrologic conditions (i.e., not a weir).

Type 2: These single-log structures are placed within the proposed crossing below every pool in the step-pool system. The structures are to be buried with only the rootwad exposed and are anticipated to remain stable up to and through the 100-year flow event through soil ballast. These stable structures will allow any mobile pieces of LWM to rack behind the stable structure and create additional step-pools in the system. The design intent is to provide pool maintenance by local backwatering and scour below the steps to provide pockets of slower-moving water. These logs will be supported by stable boulder features to provide moderate stability and racking opportunity with future recruited logs.

Type 3: These LWM structures are placed downstream of the proposed crossing and contain one log piece with a rootwad and two log pieces without rootwads placed over the channel. The structure is to be placed with the two smaller log pieces interacting with the low-flow channel. The larger log pieces provides self-ballast while interacting with the high flows. These structures provide local turbulence through local redirection of flow and provide complexity through local scour and deposition. These are anticipated to remain stable up to and through the 100-year flow event by virtue of the structures' weight, configuration, and orientation, which must be verified in the FHD and fortified if necessary through soil ballast or anchoring.

Type 4: These LWM structures are surface-placed downstream of the proposed crossing. These structures consist of three layers; the top layer is three log pieces with rootwads over the middle layer, made up of two log pieces without rootwads over a base layer, made up of two smaller log pieces. The base layer is placed at a skew to the flow direction with the pieces engaged at bankfull flow to provide hydraulic roughness and aquatic habitat at all flows. The middle layer is also placed at a skew to the flow direction with additional engagement at bankfull flow to promote redirection of the stream and roughness during high-flow events; the top layer is placed orthogonal to flow direction with engagement from the root wad at high-flow events with the intent of this piece to ballast the structure so that it maintains its integrity during high-flow

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events. The large number of pieces in this structure is meant to provide regions of high-flow refugia, to offer a more-complex habitat structure, and to develop controlled scour and potential dislodgement of smaller pieces.

All LWM stability calculations will be completed in the FHD to validate the stability of all LWM structures and help determine whether anchoring is needed. No structure type is designed to change channel planform, but facilitate in-channel change, such as local scour and deposition. Preformed pools are recommended around larger rootwads to anticipate future scour. All pools, preformed or not, would provide resting areas for the fish listed in Section 2.4. Additional habitat components of the proposed design include pools for slower velocities, LWM for additional shade, and food-sourcing promotion of aquatic organisms for fish. The proposed channel was designed to maintain a low-flow area; however, a seasonal hydrologic analysis was not performed as the channel complexity features will promote concentrated low-flow areas to reduce fish stranding and barriers.

As previously noted in Sections 2.4 and 2.6.3, the reach within the project area may be utilized by salmonids for migration, rearing, feeding, and spawning. The proposed design improves ecological integrity by providing LWM in all structure types that interacts with the low-flow channel and a less-straightened channel, which provides instream habitat for all aquatic organisms. Additionally, all of the proposed LWM upstream and downstream of the proposed crossing is surface placed and self-ballasted rather than buried, which allows for a lesser grading and clearing impact. With a smaller footprint, more existing riparian vegetation can remain in place and continue to function properly, with well-developed rootmass to help stabilize banks, a well-developed canopy to provide shade and LWM recruitment, and a developed understory.

The proposed LWM design, particularly the use of LWM within 50 feet of the structure and beneath the structure, has been discussed in detail and agreed upon with WSDOT's HQ Hydraulics.

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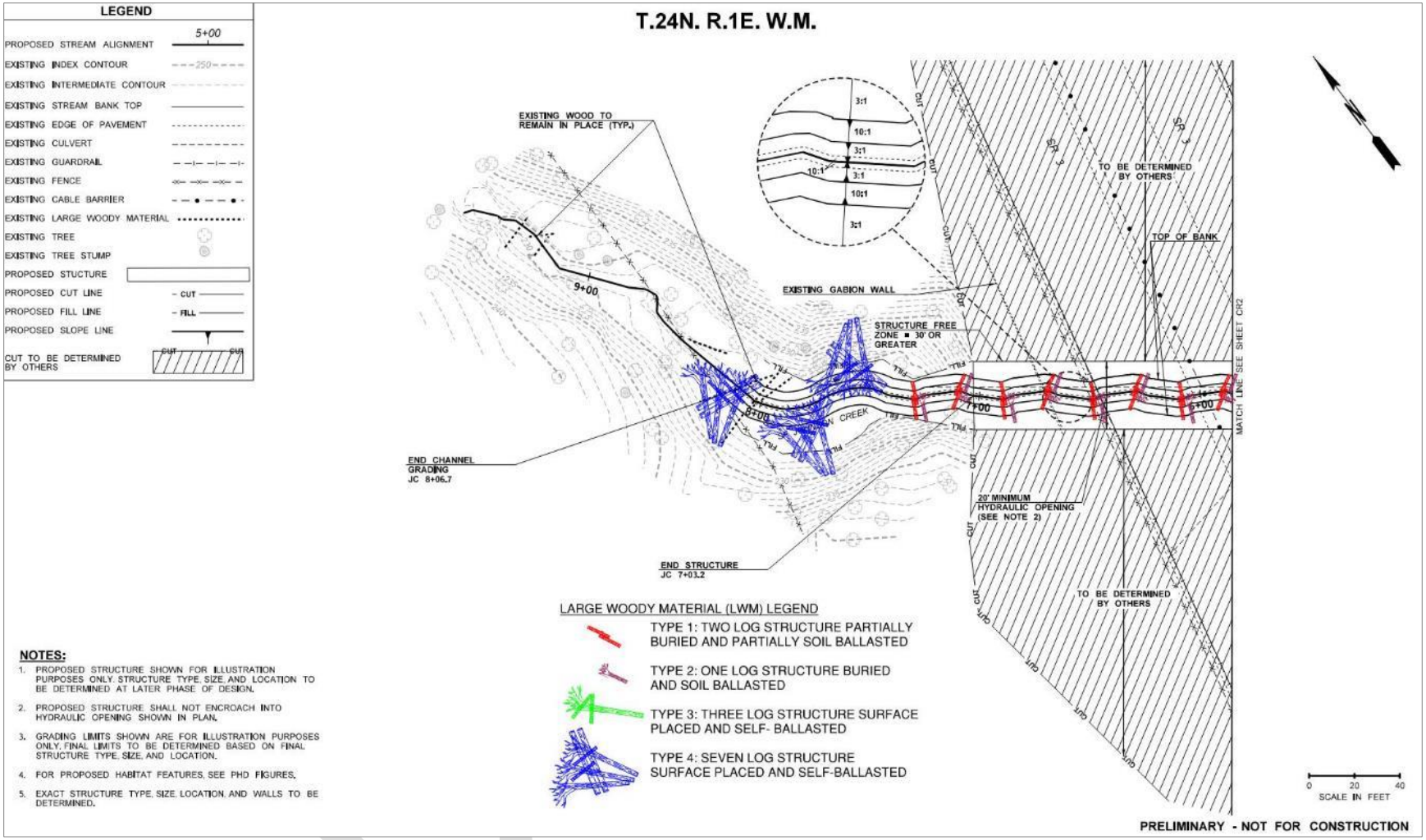


Figure 28: Upstream conceptual layout of habitat complexity

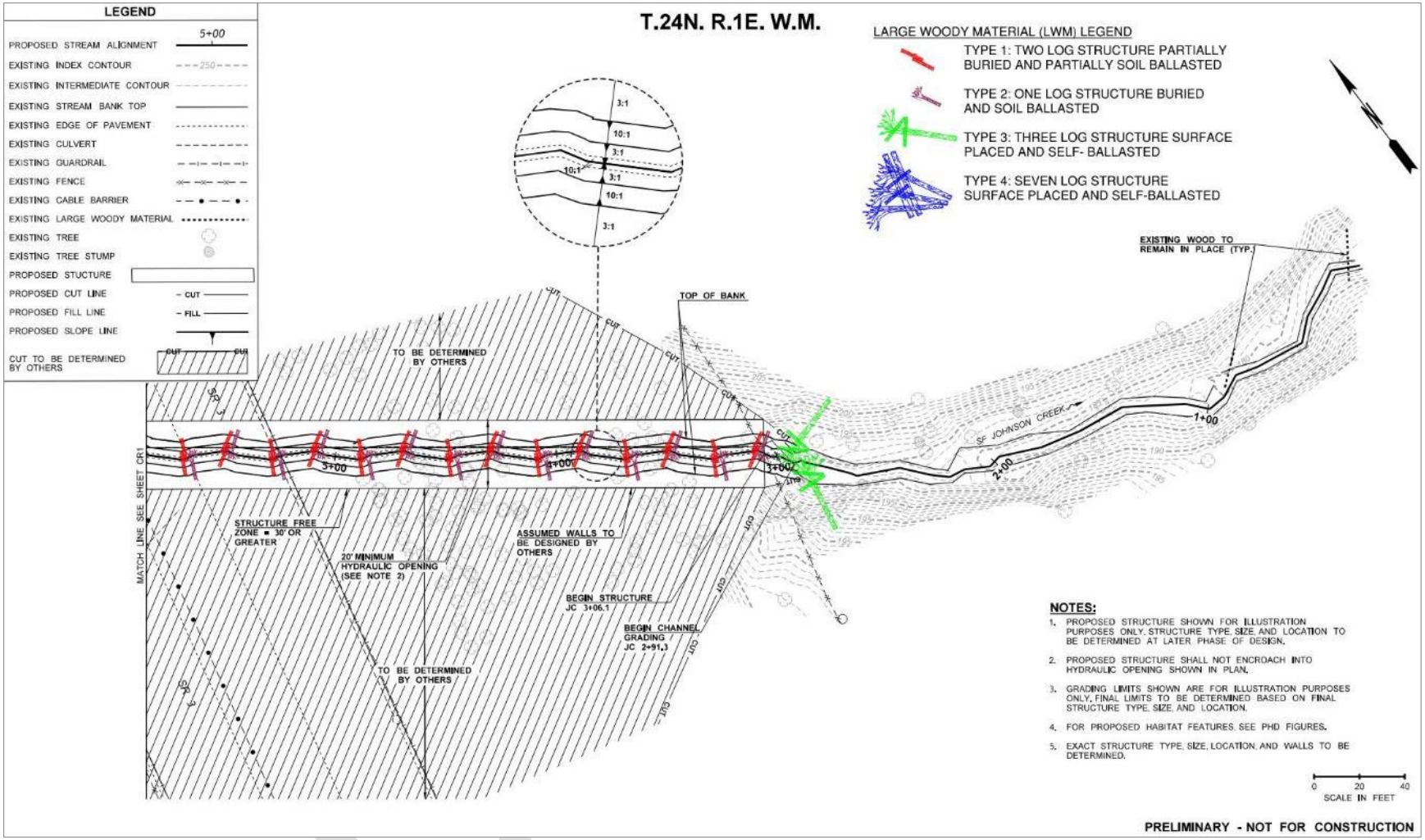


Figure 29: Downstream conceptual layout of habitat complexity

4.3.2.2 Stability Analysis

Large wood stability analysis will be completed at final design.

4.3.2.3 Step-Pool Design Details

While the overall proposed gradient through the structure is 7.3 percent, the proposed design should include steps and pools, rather than a 400-foot-long cascade, as agreed upon by all attendees of the comanager concurrence meeting on December 17, 2021. To mimic the step-pool metrics measured in the reference reach (Section 2.7.1), the proposed pools are generally 5 feet long and spaced on average every 20 feet. Between each pool is a 15-foot cascade at a slope of 7.3 percent. The step height, measured from bottom of pool to top of step (LWM), has a 1.2-foot topographic step height. Figure 30 shows a detailed profile with steps and pools. Step height is limited due to the maximum hydraulic drop being limited to 0.8 foot, as specified in WDFW's WCDG (Barnard et al. 2013) to prevent fish stranding. Section 5.4 describes the WSEs at different flow events.

The proposed step geometry is identical to the typical cascade geometry as describe in Section 4.1.2. The main difference is that Type 1 LWM structures will be placed at every step in the step-pool system and consist of two smaller logs in sequence (Figure 31). These structures are to be partially buried and mimic the evolution of the stream and to not have a hardened step-pool system within the structure. The typical pool cross section of each pool is described in Section 4.1.2. As design progresses, boulders should be considered to supplement the wood design, to aid in the longevity of design, and for future recruitment of the LWM steps.

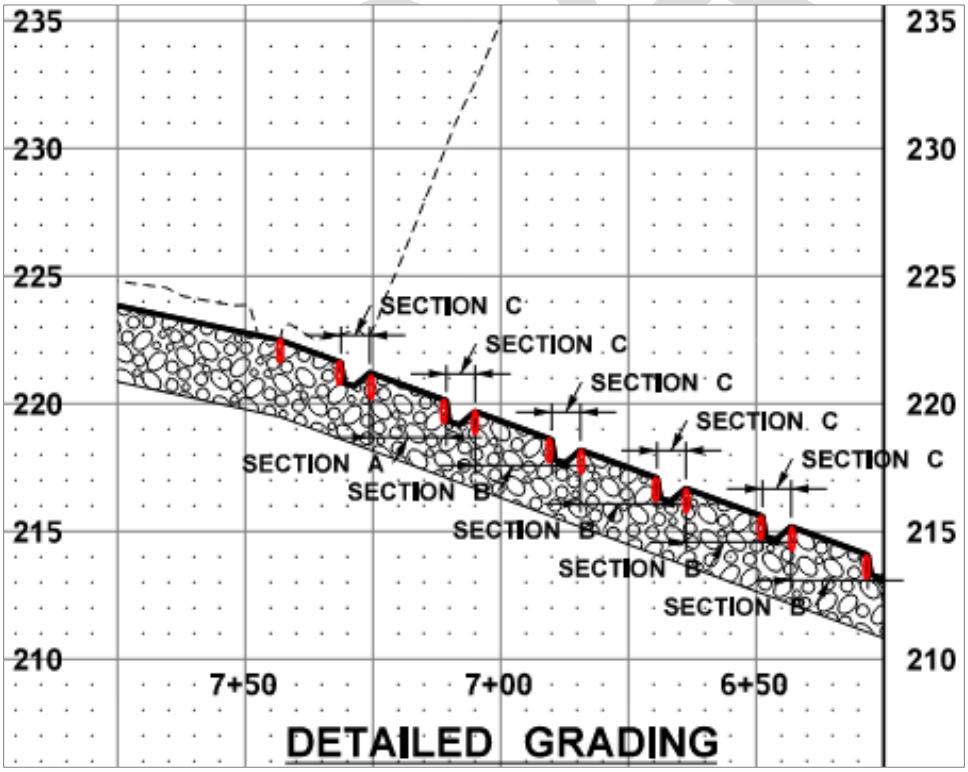
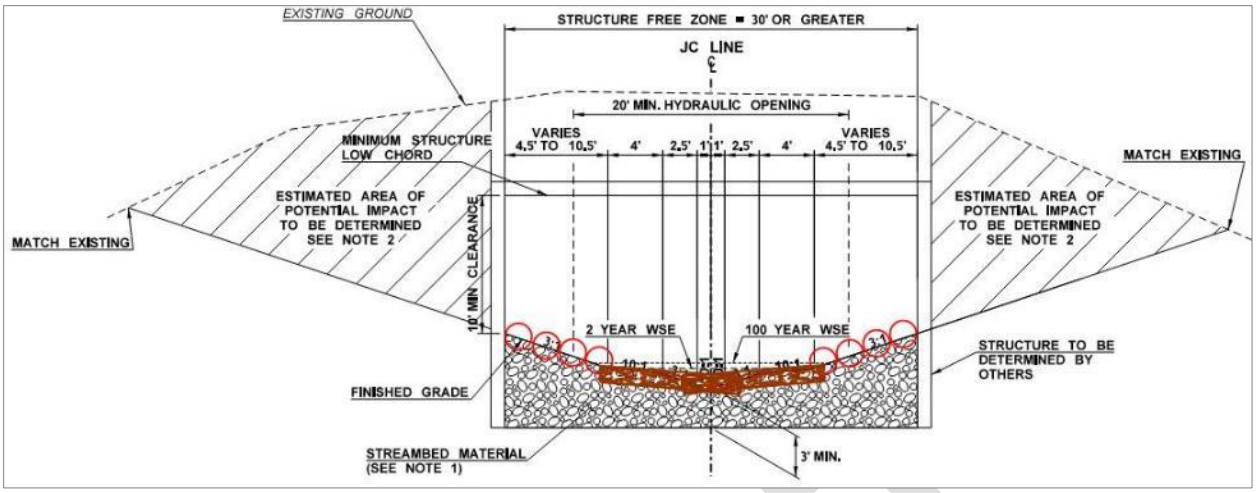


Figure 30: Step-pool profile details (red circles designate proposed one-man boulders as grade control)



Note: The LWM are tipped vertically and horizontally to provide variable flow paths in all flow conditions.

Figure 31: Typical step cross section details (brown blocks designate proposed Type 1 LWM structures, red blocks designate floodplain that will be more stable).

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5 Hydraulic Analysis

The hydraulic analysis of the existing and proposed SR 3 MP 50.85 SF Johnson Creek crossing was performed using the U.S. Bureau of Reclamation's Sedimentation and River Hydraulics – Two Dimension (SRH-2D) Version 3.3.0 computer program, a 2D hydraulic and sediment transport numerical model (2020). Pre- and post-processing for this model was completed using SMS Version 13.1.16 (Aquaveo 2020).

Two scenarios were analyzed for determining stream characteristics for SF Johnson Creek with the SRH-2D models: (1) existing conditions simulating the existing 36-inch-diameter, 400-foot-long culvert and (2) proposed conditions with the proposed 20-foot minimum hydraulic opening with a structure-free zone of 30 feet or greater installed. Appendix H provides a complete set of output figures.

5.1 Model Development

This section describes the development of the model used for the hydraulic analysis and design.

5.1.1 Topographic and Bathymetric Data

The channel geometry data in the model were obtained from the MicroStation and InRoads files supplied by the WSDOT Project Engineer's Office, which were developed from topographic surveys performed by WSDOT in September 2021. The survey data were supplemented with LiDAR data (USGS and Quantum Spatial 2018). Additional details within the reference reach not captured by the field survey, such as large wood and scour pools, were added to the topographic surface by the design team and modeled in the reference reach submodel. The additional details in the reference reach were added to aid the step-pool design and reference comparison to the proposed-conditions model results; design drawings do not include this additional detail. Ptarmigan Lane NW is a 10-foot roadway embankment across SF Johnson Creek, roughly 100 feet downstream of the model boundary. As a potential hydraulic control, the downstream boundary could reflect backwater from the 3 feet culvert, which conveys flow beneath Ptarmigan Lane NW. However, this does not backwater into the reference reach or SR 3 crossing.

The proposed channel geometry was developed from the proposed grading surface created by the design team. All survey and LiDAR information is referenced against the North American Vertical Datum of 1988 (NAVD88).

5.1.2 Model Extent and Computational Mesh

The existing- and proposed-conditions model meshes include approximately 38,400 and 49,400 elements, respectively, across an area of approximately 18.5 acres. The mesh was constructed with quadrilaterals that are approximately 9 to 14 inches wide, varying with channel width, and 12 inches long in the main channel; the overbank mesh was constructed with triangles with edge lengths that vary from 12 inches near the main channel to 4 feet at the exterior of the model domain (Figure 32 and Figure 33). The main channel is modeled with at least eight elements across to sufficiently capture the channel within the mesh.

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Survey data extends approximately 318 feet downstream and 257 feet upstream of the existing crossing (Figure 32 and Figure 33). The model extends an additional 100 feet farther downstream than the survey, using supplemental LiDAR data and a channel stamped into the mesh. This was done to obtain accurate results through the reference reach, which is located near the downstream edge of the channel survey. The existing alignment starts at Station (STA) 0+00 at the beginning of the channel survey (Figure 33).

A detailed submodel of the reference reach was constructed to characterize the existing hydraulic conditions at the sub-1-foot scale. This model mesh, shown on Figure 34, extends from STA 0+00 to STA 1+40 and contains approximately 44,500 elements that range between 0.2 to 0.5 square feet. The reference reach model includes four steps in the terrain, which represent channel-spanning large wood that form the step-pool morphology. These channel-spanning wood features act as extensions of the terrain, rather than flow resistance or drag, which is applied uniformly to the water column. The proposed-conditions mesh contains dense mesh elements concentrated between STA 6+70 to STA 7+30 (Figure 35), where the proposed design has a series of four step-pools, above and below this location the grading is simplified and the model mesh less focused. Section 5.4 provides additional details regarding the proposed design elements.

A gap exists between upstream and downstream plan views (Figure 32 and Figure 33) of roughly 200 feet (STA 4+00 to STA 6+00) over SR 3, which has a consistent mesh. The existing-conditions model is continuous where not shown.

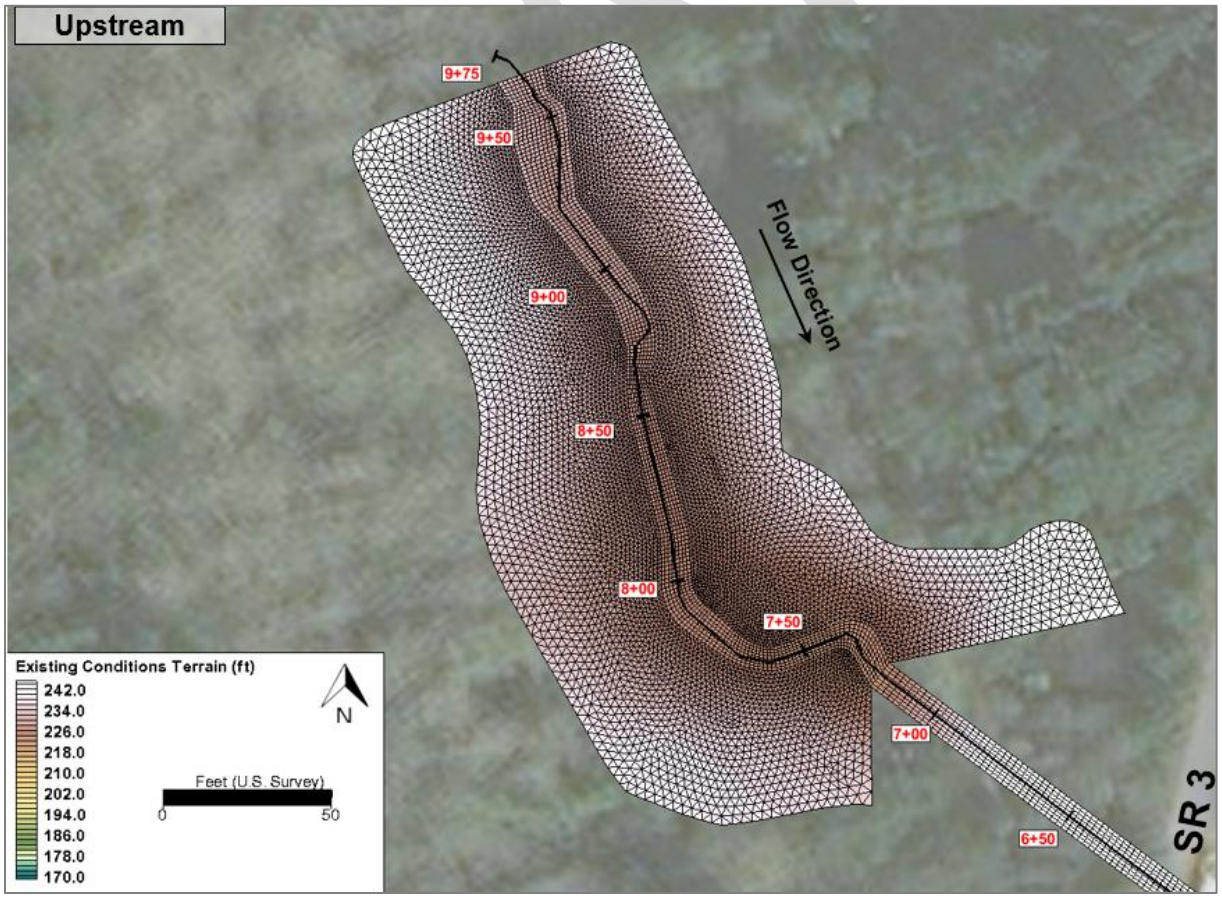

Figure 32: Upstream portion of the existing-conditions computational mesh with underlying terrain

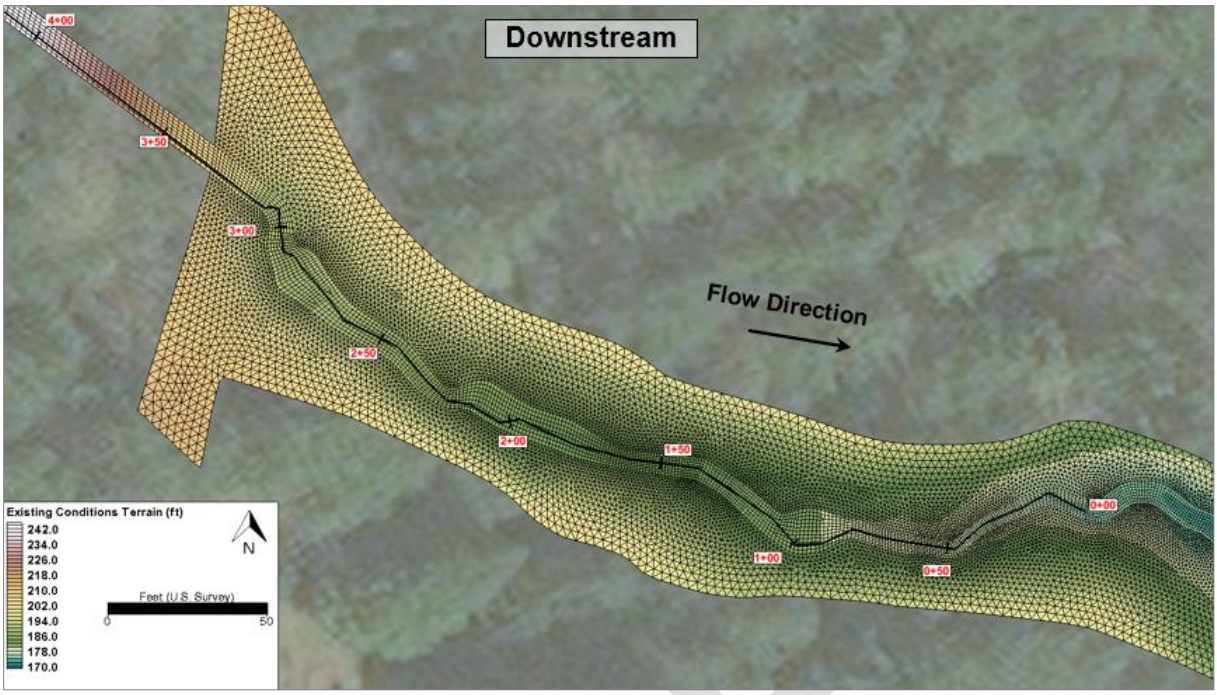

Figure 33: Downstream portion of the existing-conditions computational mesh with underlying terrain

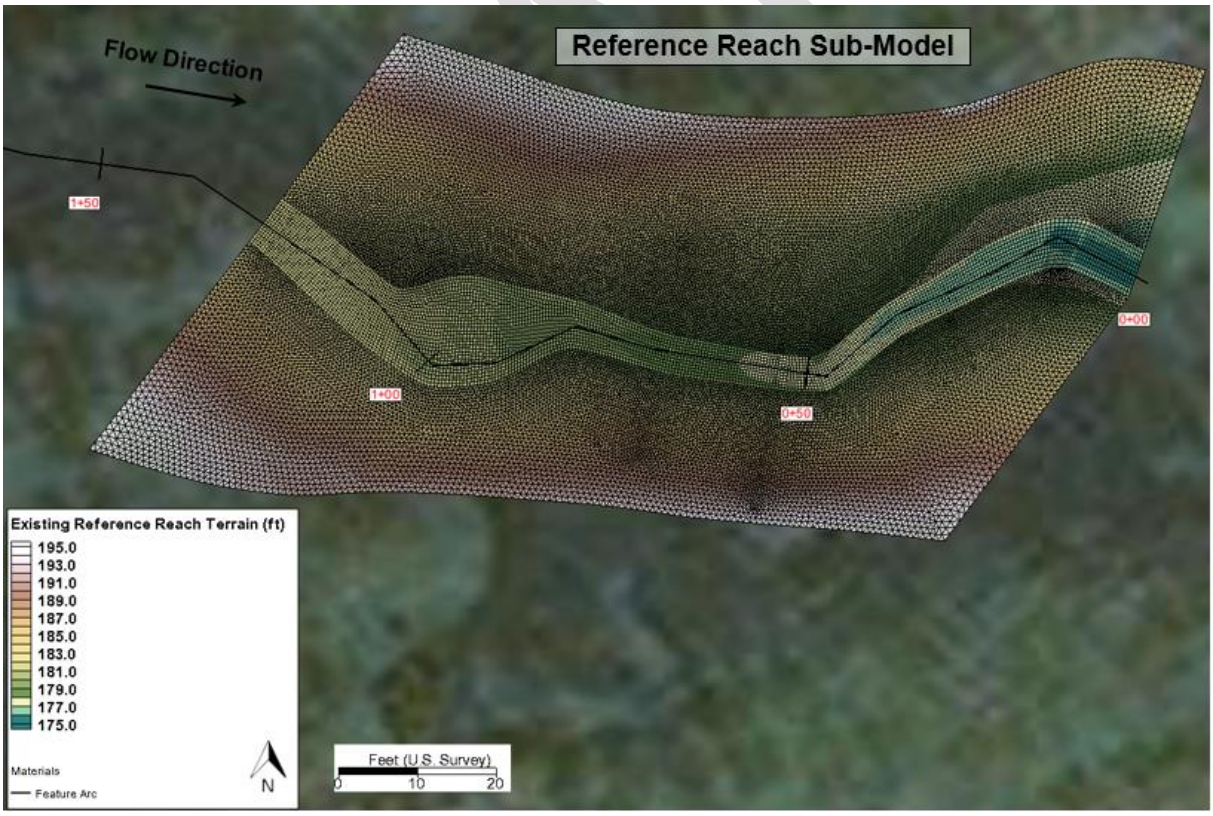

Figure 34: Detailed reference reach existing-conditions computational mesh with underlying terrain

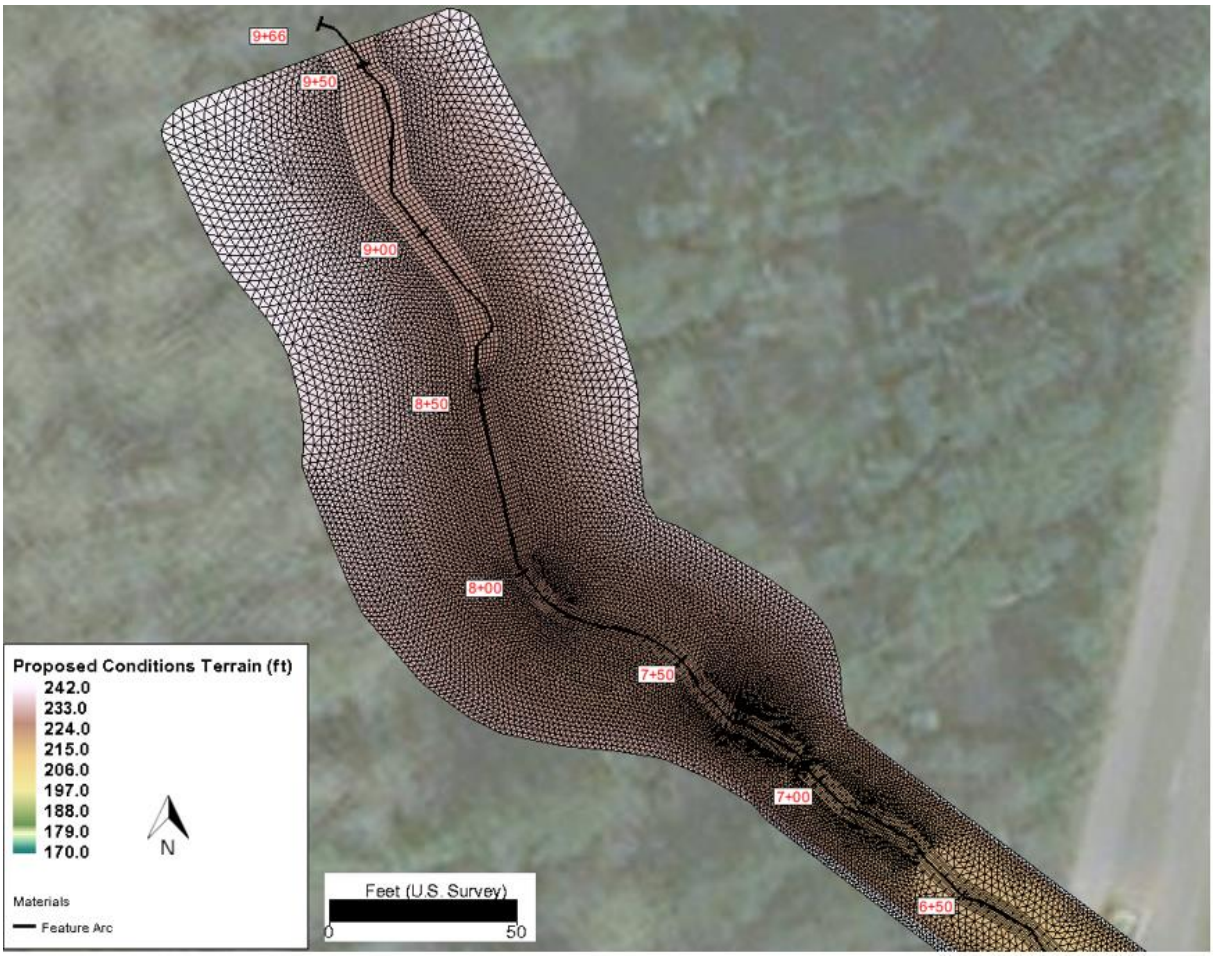

Figure 35: Upstream portion of the proposed-conditions computational mesh with underlying terrain

5.1.3 Materials/Roughness

The roughness coefficient is a composite value representing two forms of flow resistance: form roughness and skin friction. Both affect hydraulic conditions (such as WSE, velocity, and shear stress) and the energy that is available to transport sediment. Form drag represents large-scale impediments to flow, including bedforms, bends, point bars, LWM, or vegetation, and is highly dependent on flow depth and velocity. Skin (or grain) friction are the individual particle characteristics interacting with fluid at the fluid/soil boundary.

Channel roughness was determined using the substrate sediment size information from US Pebble Count 1 and REF Reach Pebble Count 1, see Section 2.7.3. A variety of empirical relationships exist between surface sediment size and roughness; however, Limerinos (1970) was based on steep-sloped streams similar in composition to the upstream reaches.

Limerinos' (1970) equation is defined below:

$$n = \frac{(0.0926 * R^{\frac{1}{6}})}{1.16 + 2.0 * log(\frac{R}{D_{84}})}$$

Where:

R = Hydraulic radius (feet)

D_{84} = Particle diameter for which 84 percent of the gradation is finer than (feet)

Roughness for floodplain and obstruction (buildings, rock, debris, etc.) coefficients were estimated using guidance from the "Guide for Selecting Manning's Roughness Coefficients for Natural Channels and Flood Plains" (Arcement and Schneider 1989) and *Open Channel Hydraulics* (Chow 1959). Proposed LWM outside of the crossing is parameterized as discrete high roughness (Table 12). Proposed wood within the crossing, which forms the step-pool sequence, is included in the proposed-conditions terrain, consistent with how the reference reach channel-spanning wood is parameterized.

Spatial distributions of roughness values in the existing conditions, detailed reference reach, and upstream and downstream proposed models are shown on Figure 36, Figure 37, Figure 38, and Figure 39, respectively.

Table 12: Manning's *n* hydraulic roughness coefficient values used in the SRH-2D model

Material	Manning's *n*	
	Existing Conditions	Proposed Conditions
Channel[a]	0.043	0.043
Floodplain[a]	0.085	0.085
Road[b]	0.022	NA
Proximal Floodplain	0.067	NA
Proposed Floodplain	NA	0.045
Proposed Channel	NA	0.038
Large Wood	NA	0.2
Rootwad	NA	0.2

a. *Hydraulics Manual*, Figure 4A-2 (WSDOT 2022).
b. *Open Channel Hydraulics*, Table 5-6 (Chow 1959).

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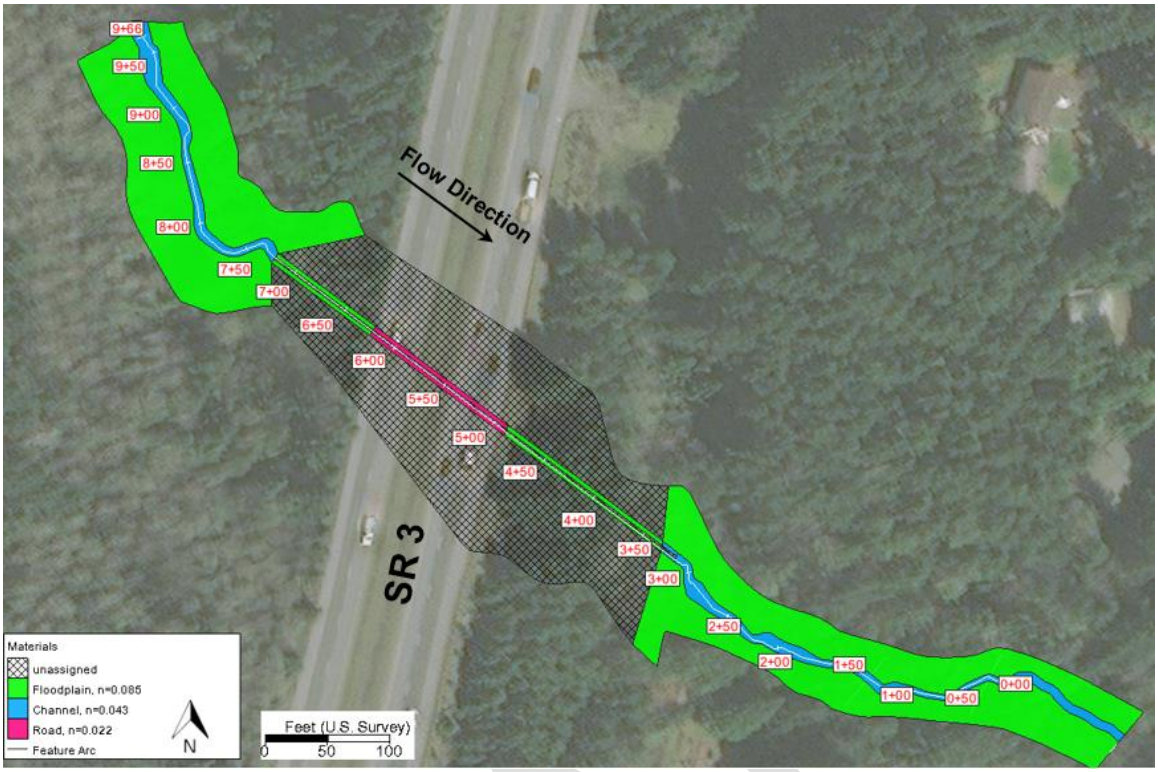

Figure 36: Spatial distribution of existing-conditions roughness values in the SRH-2D model.

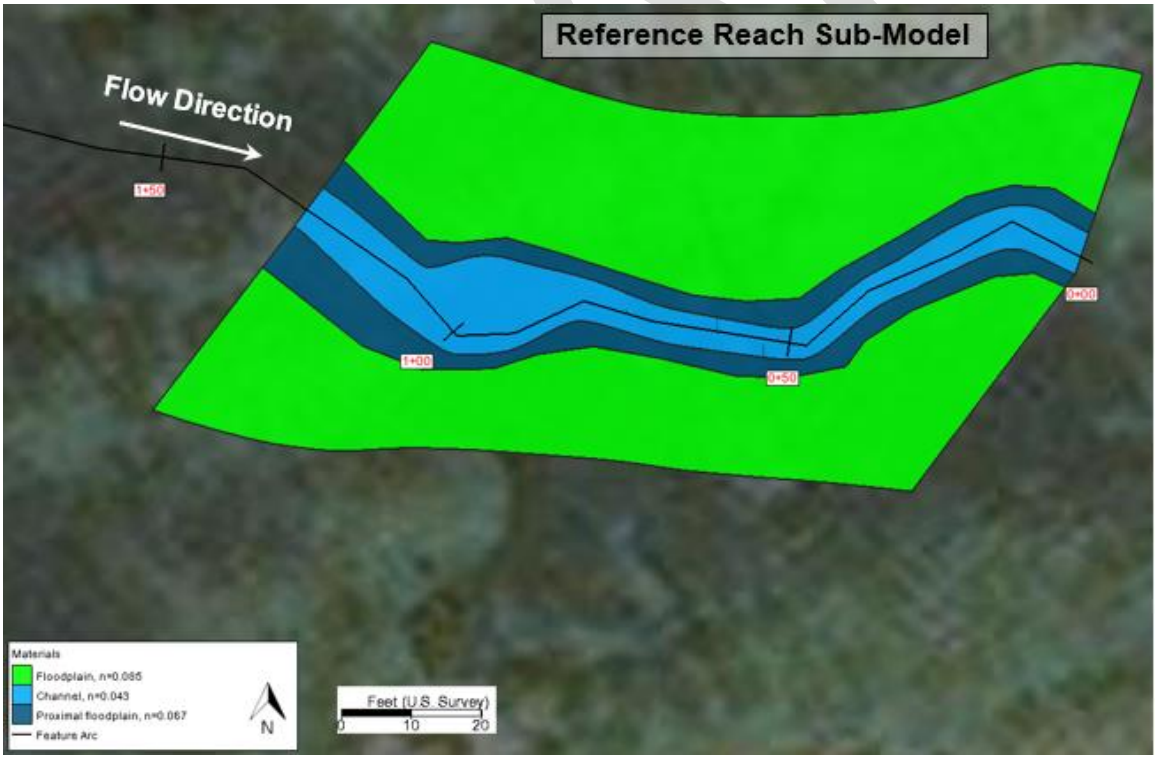

Figure 37: Spatial distribution of detailed reference reach existing-conditions roughness values in the SRH-2D model with LWM showing in the background.

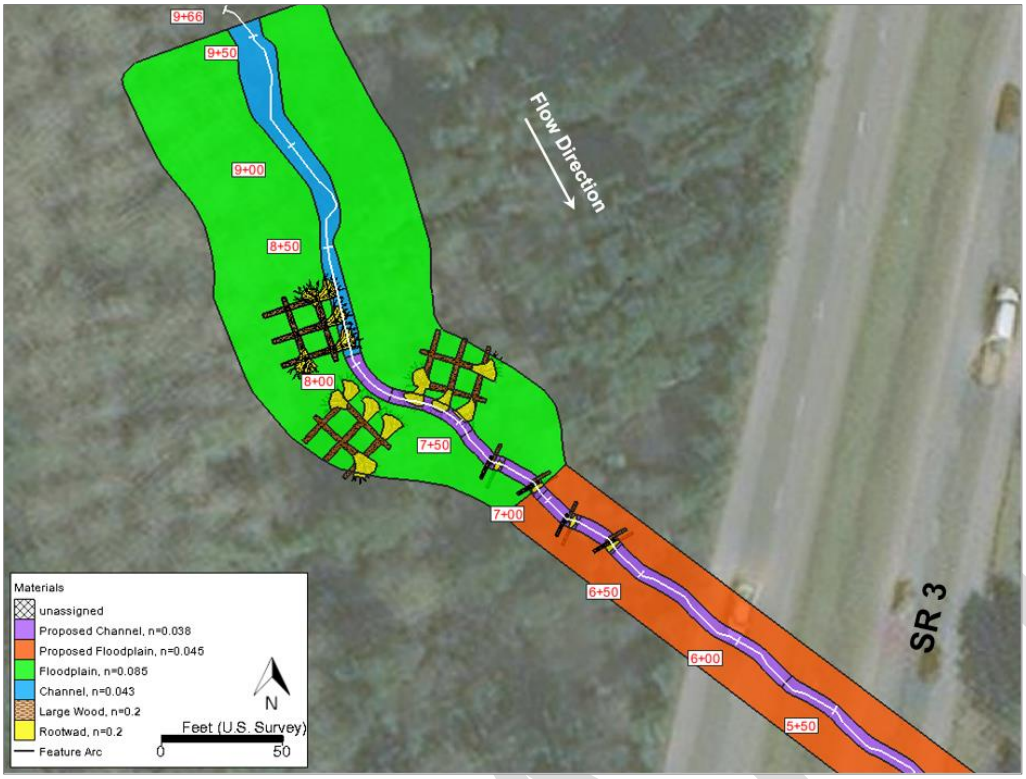

Figure 38: Upstream portion of the spatial distribution of proposed-conditions roughness values in the SRH-2D model.

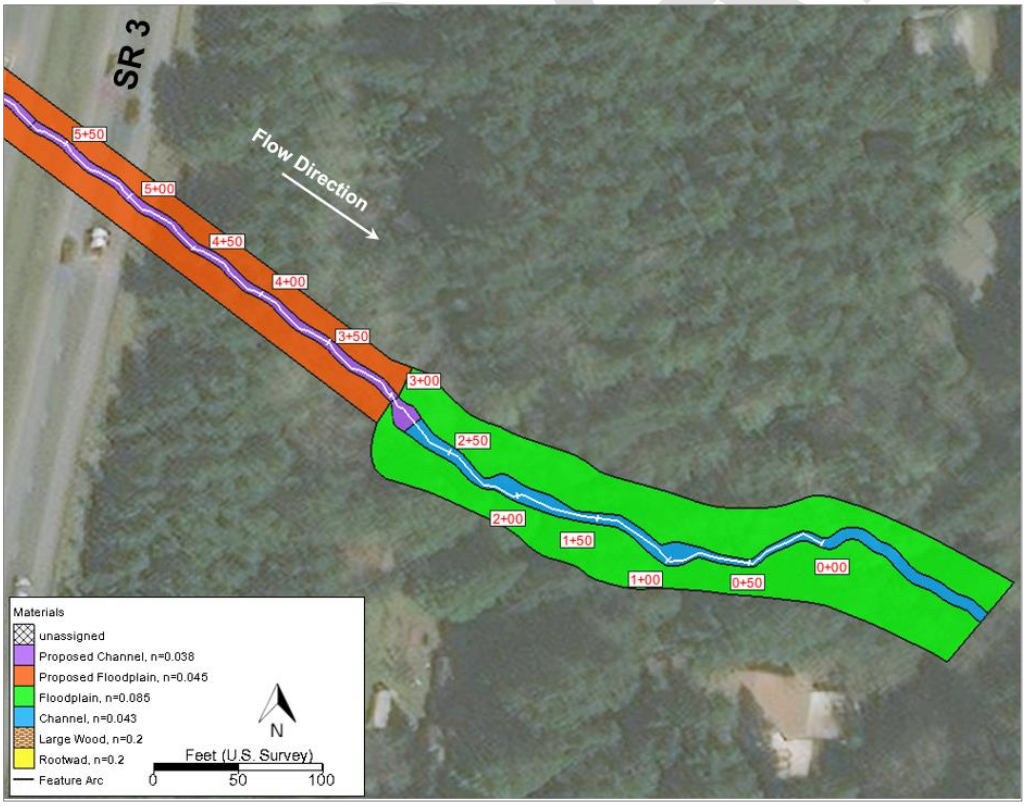

Figure 39: Downstream portion of the spatial distribution of proposed-conditions roughness values in the SRH-2D model.

5.1.4 Boundary Conditions

There is a single inflow and outflow boundary condition for the existing- and proposed-conditions models on SF Johnson Creek. The existing culvert was modeled using an HY-8 Culvert Hydraulic Analysis Program (HY-8; Federal Highway Administration 2021) culvert boundary condition arcs to convey flow through SR 3; Figure 40 shows specifics of the culvert properties. The inflow is a quasi-steady (constant) inflow hydrograph and the outflow is a stage (water level) based on discharge and uniform manning's flow assumptions (normal depth). Figure 41 shows the downstream boundary condition rating curve. Figure 42 and Figure 43 show the locations for all boundary conditions for the existing and proposed models, respectively. The reference reach submodel has the same quasi-steady state inflow hydrograph and outflow stage boundary conditions and is shown on Figure 44.

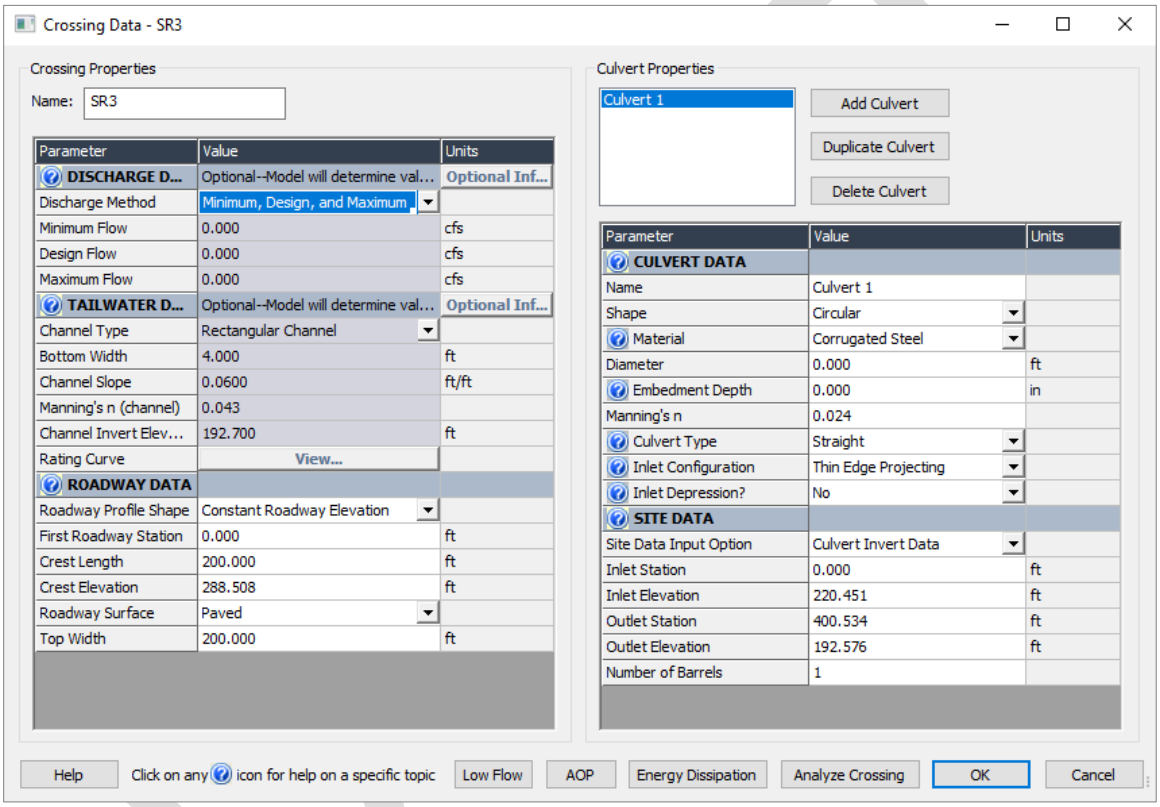

Figure 40: HY-8 culvert parameters

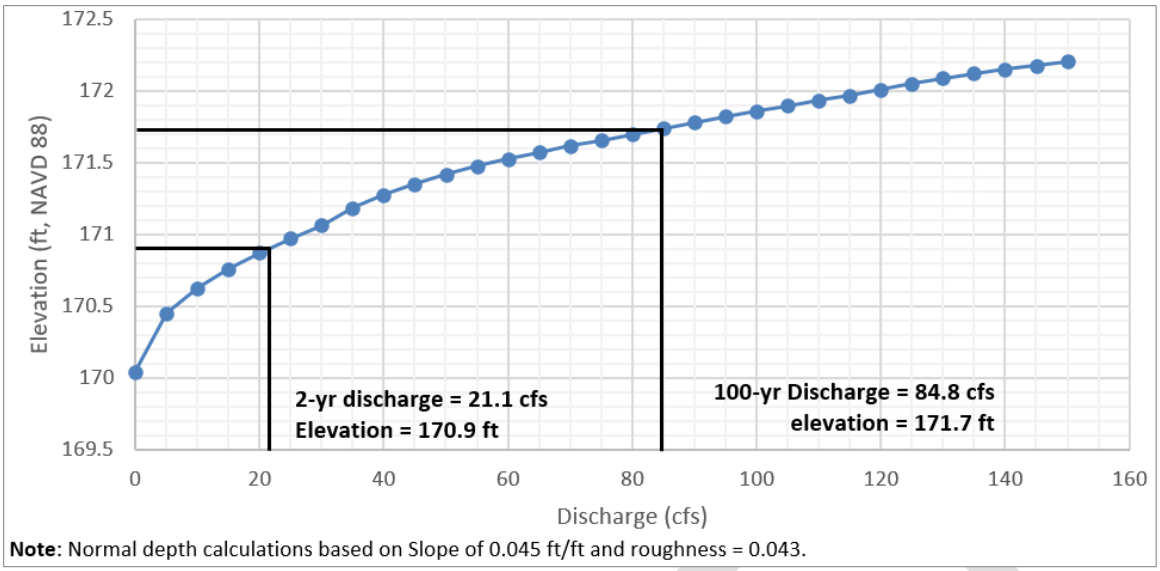

Figure 41: Downstream outflow boundary condition normal depth rating curve

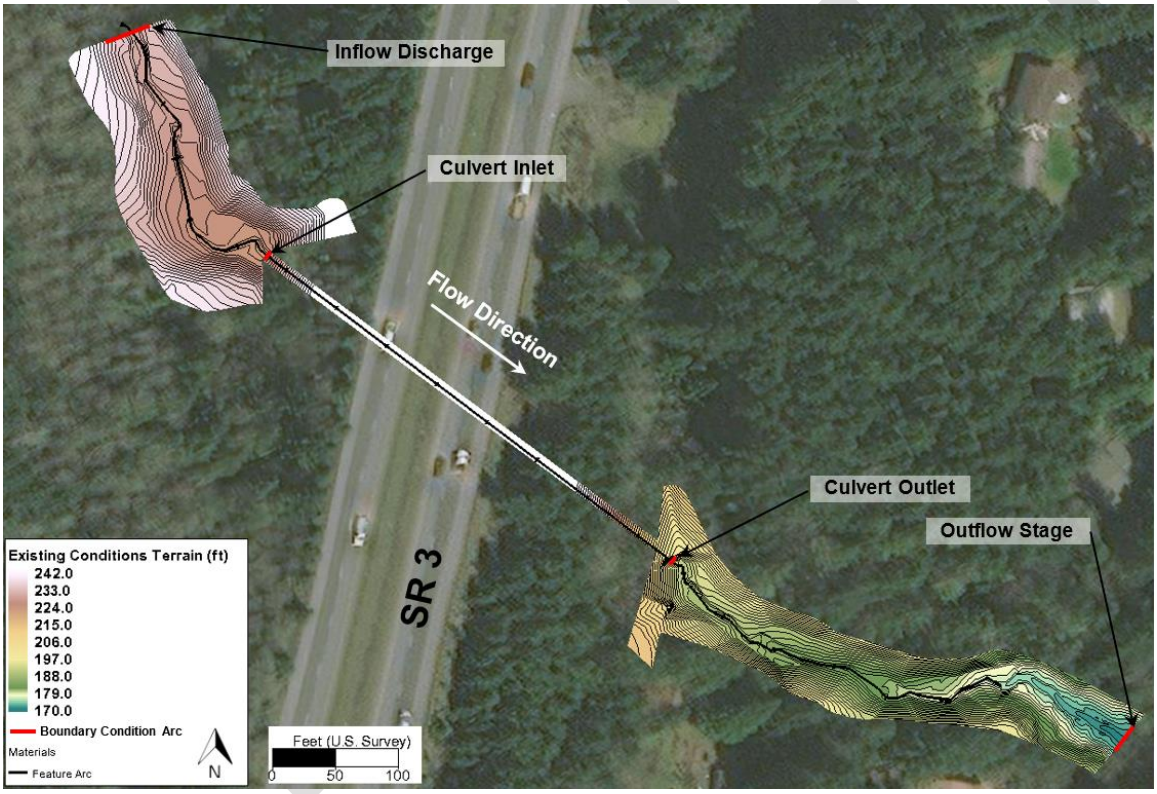

Figure 42: Existing-conditions boundary conditions

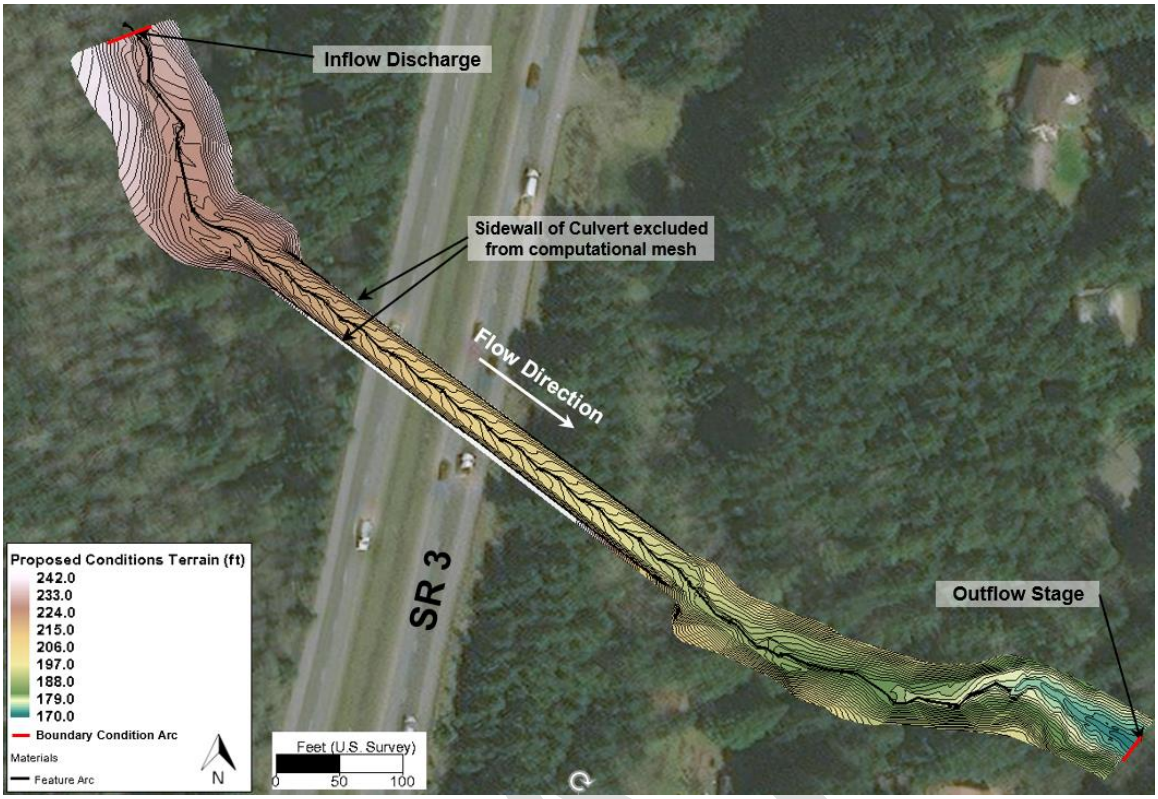

Figure 43: Proposed-conditions boundary conditions

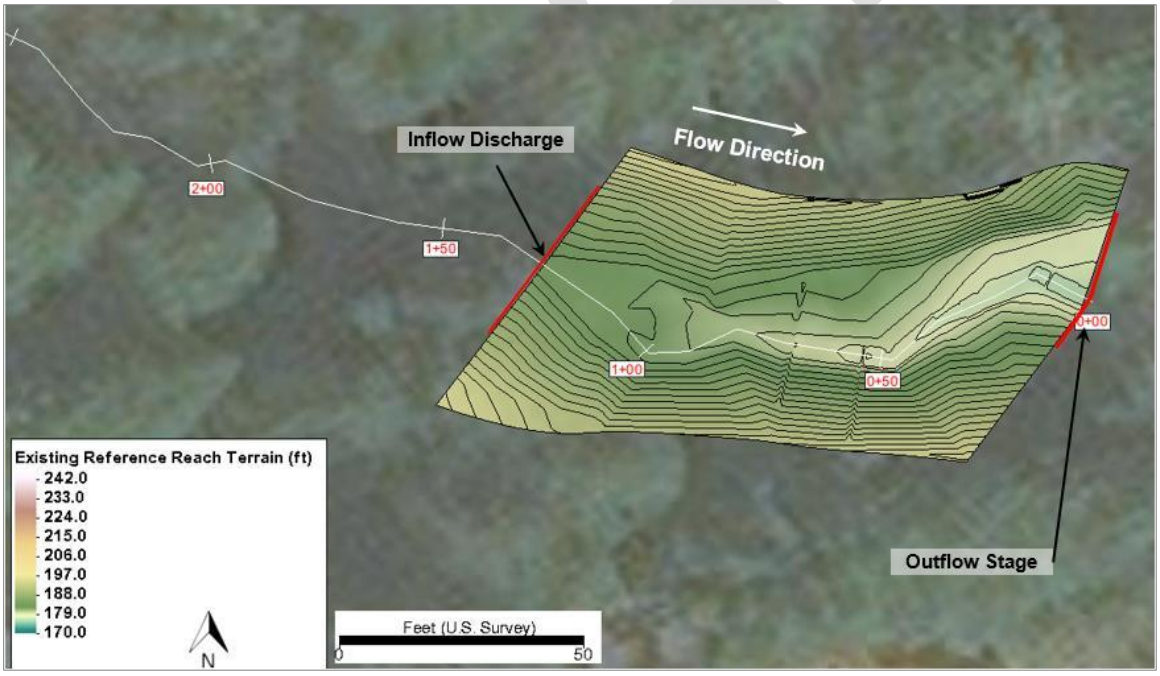

Figure 44: Existing-conditions reference reach boundary conditions

5.1.5 Model Run Controls

The design team ran the existing- and proposed-conditions scenarios for 3 hours; the outlet of the model domain reached a stable steady-state condition after approximately 1 hour. Appendix I contains additional information regarding model stability. Other parameters were set as follows:

- Start time is default 0.0 hour
- Time step is default 0.1 seconds
- End time is 2.0 hours
- Initial conditions value is default dry
- Flow module was default parabolic and parabolic turbulence of 0.7
- Output frequency is set at 15 minutes

5.1.6 Model Assumptions and Limitations

The hydraulic model is limited by the quality, density, and accuracy of each data input and how the information is parameterized by the model. A few notable limitations of the hydraulic model are summarized below:

- The model assumes constant flow resistance across flow depths. In reality, at lower-flow depths, friction is a larger component of fluid motion.
- The model is 2D in the x and y directions based on the spacing and orientation or the grid cells and depth integrated, meaning vertical advection or diffusion of momentum is assumed to be negligible relative to the x and y directions. This is colloquially stated as the “shallow water” assumption and is valid in most fluvial environments.
- The model assumes constant flow resistance across flow depths and is limited to using Manning’s *n* to characterize resistance, which is independent from flow depth. At lower-flow depths, friction is higher relative to larger-flow depths. Flow resistance, particularly on the floodplain, also varies seasonally as deciduous trees and shrubs shed their leaves in winter.
- The model is fixed bed; all features are static. At flood stage, aggradation and degradation create pools and gravel bars and change the channel morphology.
- All reported model outputs are main channel averages except for depth, which is a true maximum value. Main channel average values represent trends in the hydraulic results, which at this stage of design is preferred over discrete peak values that may lead to an overly conservative design, based on limited information.
- The hydraulic model does not account for infiltration loss or hyporheic inflow.

5.2 Existing Conditions

The existing-conditions model and reference reach submodel were run for the 2-year, 100-year, and 500-year design events based on the selected design flows as described in Section 3. The average hydraulic results for WSE, velocity, and shear stress are reported in Table 13, along with maximum depth at each cross section. The respective cross section locations for reporting are shown on Figure 45. Results for DS 11 STA 1+20 and DS 13 STA 0+74 are extracted from the reference reach submodel. Low-flow considerations were not analyzed as part of the PHD; this will be investigated as part of future design phases.

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The existing culvert is undersized for the 100- and 500-year events and creates a submerged (pressure flow) culvert condition with headwater elevation of roughly 4 and 8 feet above the top of pipe, for each respective event. The backwater extends roughly 150 and 200 feet upstream for each respective event (Figure 46). As discussed in Section 3, the 2-year event was scaled to match bankfull flow based on the field survey data and therefore closely matches bankfull conditions throughout the domain, as the recurrence interval for the bankfull is unknown without gauge data.

The channel profile is steeper downstream of the crossing, with a channel average slope of 5.7 percent compared to 3.3 percent upstream of the crossing. In turn, velocities downstream of the crossing are higher, as shown in Table 14. The reference reach is located between STA 0+00 and STA 1+40, the lower portion of the model domain, in part because the profile most closely matches the existing culvert, which is on a 7.2 percent slope (described further in Section 2.7). The reference reach is characterized by confined steep valley walls with forced step-pools created by woody debris accumulations separated by short riffles. High main channel shear stress and velocities are dissipated by this planform roughness to provide a stable channel. Figure 47 shows a profile of WSE and velocity based on the reference reach submodel. Velocities in the pools range from 5 to 6 fps, while velocities over the steps range from 8 to 9 fps. This information was used as a basis for the proposed step-pool design.

Figure 48 shows a typical section from the reference reach at STA 0+74 for the scenarios that were evaluated. Figure 49 and Figure 50 show the 100-year velocity in plan view; the reference reach, shown as an inset on Figure 50, has a wide variation in velocity as flow interacts with the channel-forming steps and features. Additional existing-conditions model results is in Appendix H.

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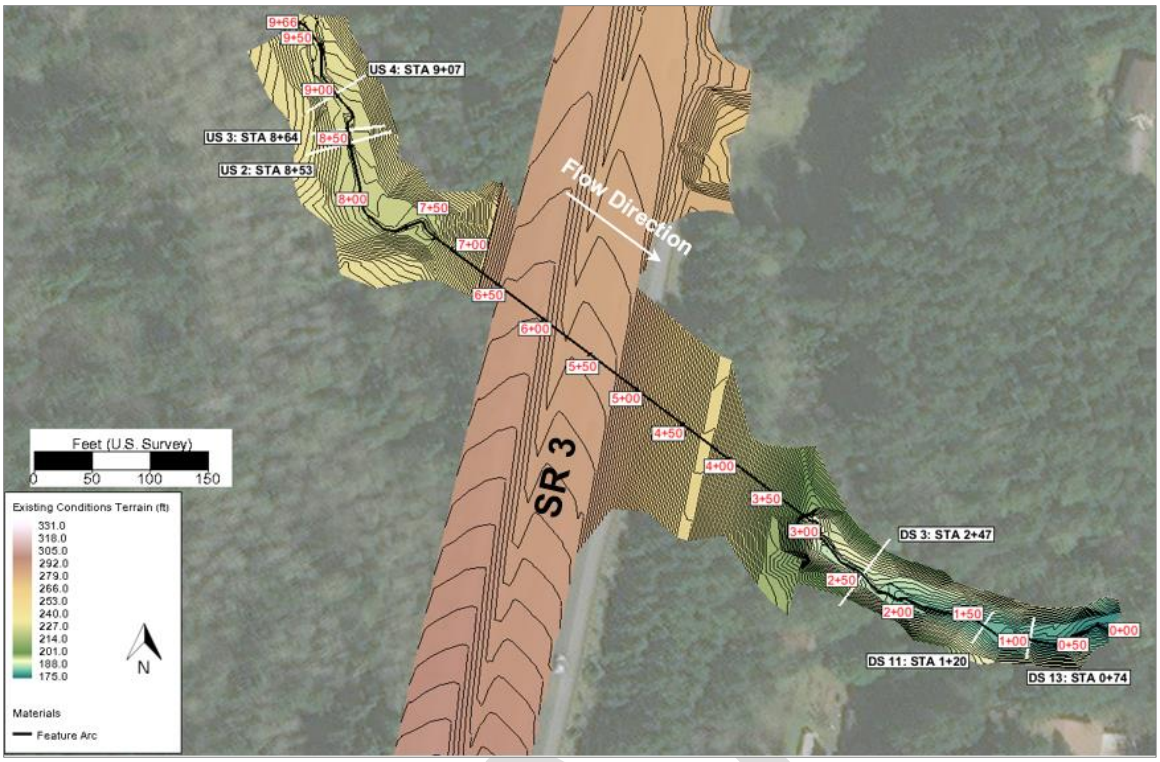

Figure 45: Locations of cross sections used for results reporting

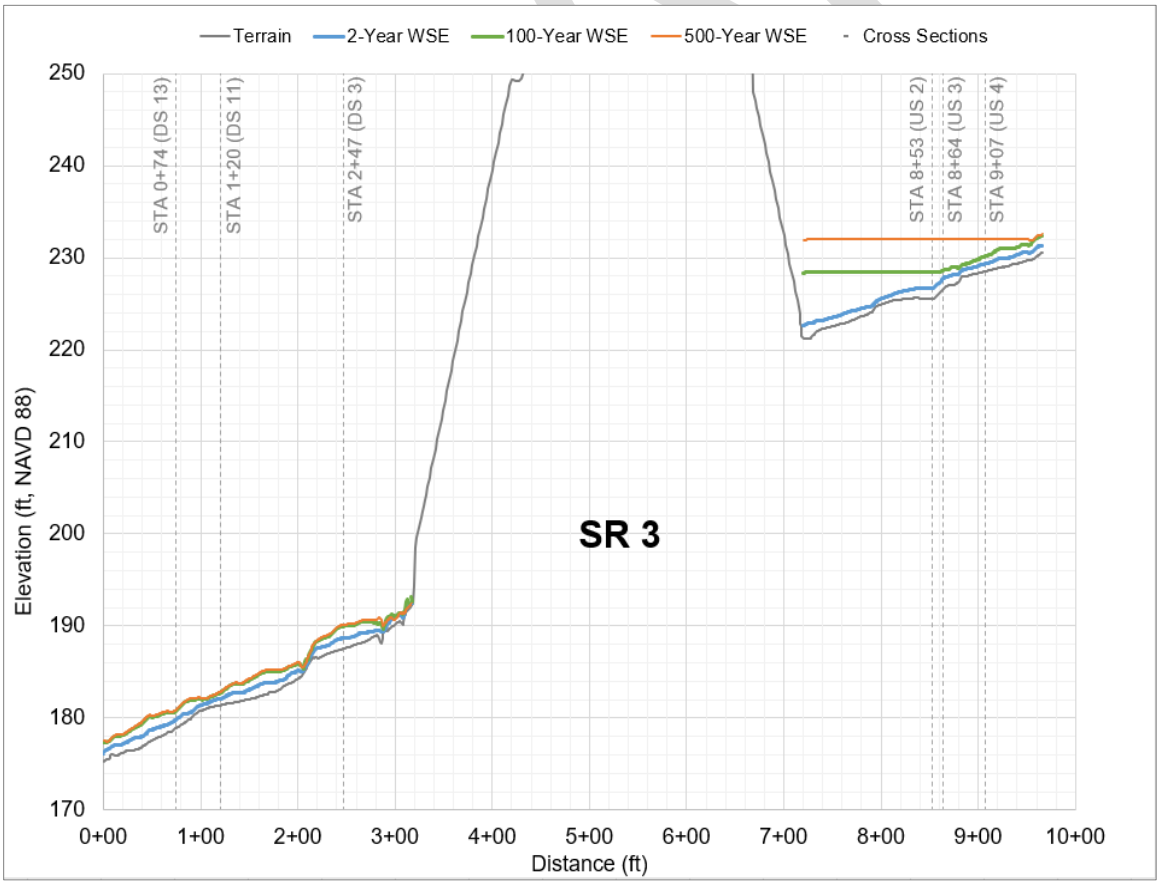

Figure 46: Existing-conditions water surface profiles

Table 13: Average main channel hydraulic results for existing conditions[a]

Hydraulic parameter	Cross section	2-year	100-year	500-year
Average WSE (ft)[b]	**US 4**: STA 9+07	229.2	229.9	232.0
	US 3: STA 8+64	227.9	228.7	232.0
	US 2: STA 8+53	226.7	228.5	232.0
	Structure	NA	NA	NA
	DS 3: STA 2+47	188.6	189.7	189.9
	DS 11: STA 1+20	181.8	182.2	182.5
	DS 13: STA 0+74	179.9	180.8	181.0
Maximum depth (ft)[b]	**US 4**: STA 9+07	0.8	1.6	3.6
	US 3: STA 8+64	1.2	2.0	5.4
	US 2: STA 8+53	1.2	3.0	6.5
	Structure	NA	NA	NA
	DS 3: STA 2+47	1.2	2.5	2.7
	DS 11: STA 1+20	0.6	1.0	1.3
	DS 13: STA 0+74	0.9	1.8	2.0
Average velocity (fps)	**US 4**: STA 9+07	4.0	5.0	1.2
	US 3: STA 8+64	3.9	3.1	0.7
	US 2: STA 8+53	5.0	2.0	0.6
	Structure	NA	NA	NA
	DS 3: STA 2+47	3.7	5.0	5.4
	DS 11: STA 1+20	2.1	5.1	8.0
	DS 13: STA 0+74	2.9	5.5	5.6
Average shear (lb/sf)	**US 2**: STA 8+53	2.0	0.5	0.1
	US 3: STA 8+64	1.1	1.8	0.1
	US 4: STA 9+07	1.2	1.9	0.2
	Structure	NA	NA	NA
	DS 3: STA 2+47	1.0	1.7	2.1
	DS 11: STA 1+20	1.5	3.2	3.4
	DS 13: STA 0+74	2.0	2.6	2.8

a. Average values defined as main channel cross-sectional averaged values.
b. Rounding can create perceived differences when comparing changes to average WSE and maximum depth, up to +/-0.2 feet.

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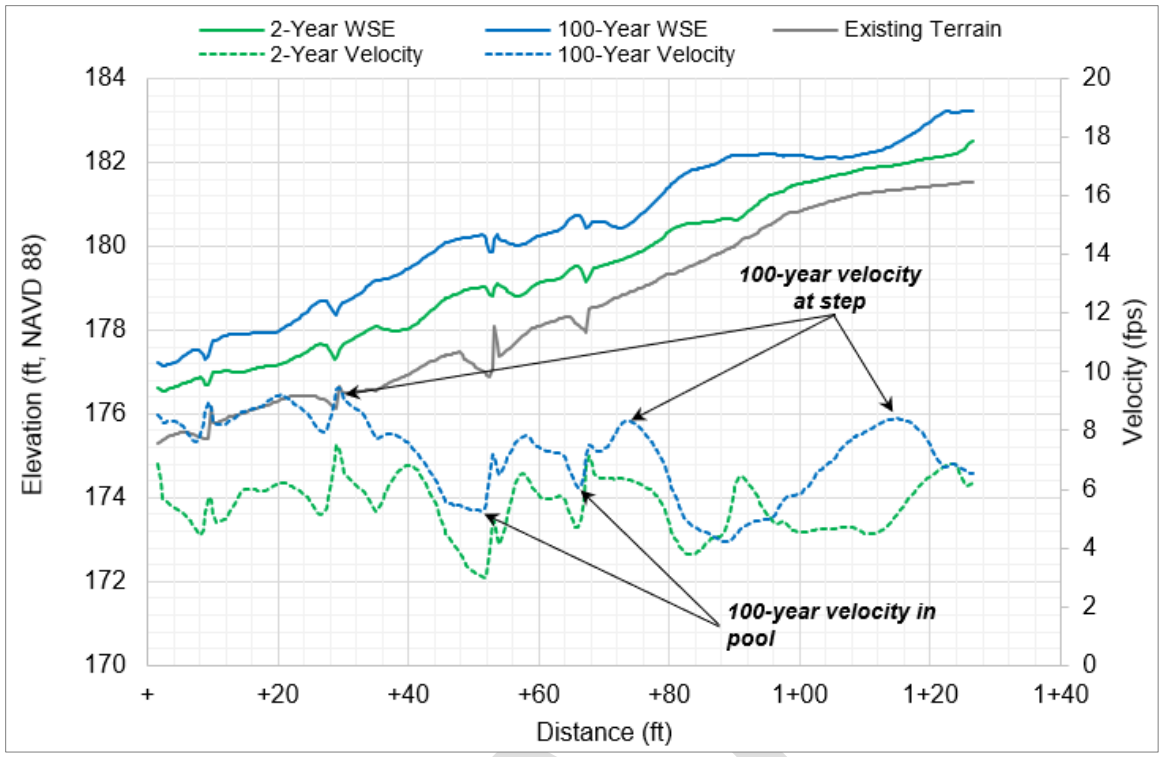

Figure 47: Existing-conditions reference reach water surface elevation and velocity profiles

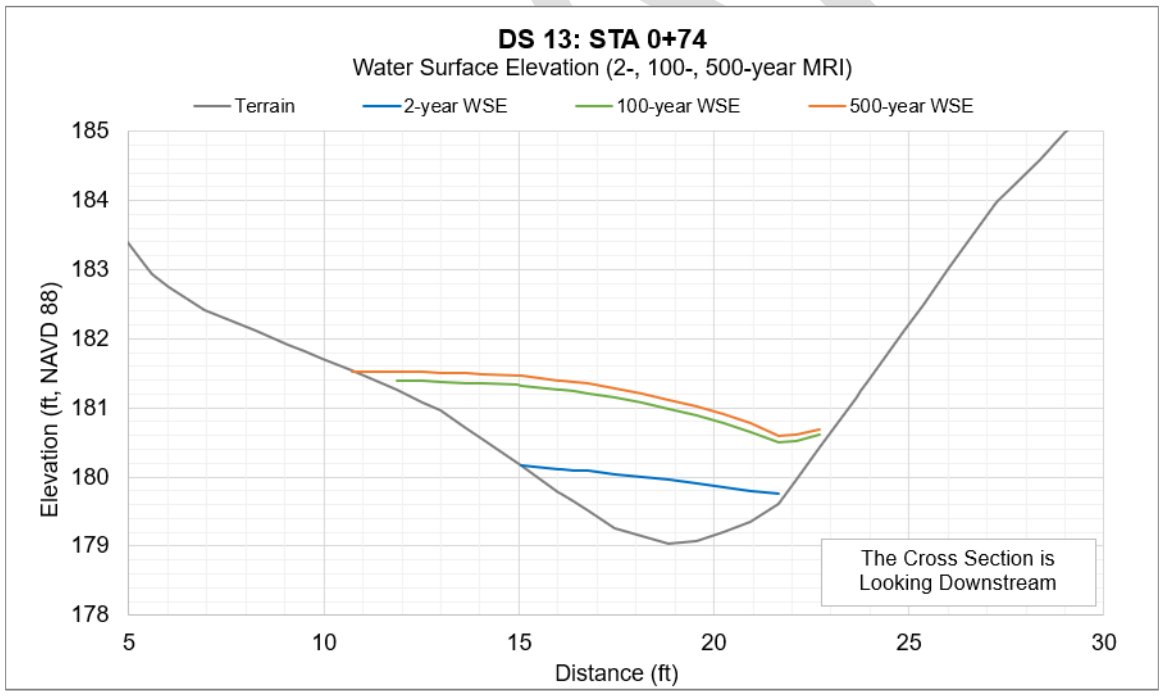

Figure 48: Typical downstream existing channel cross section through a run (STA 0+74)

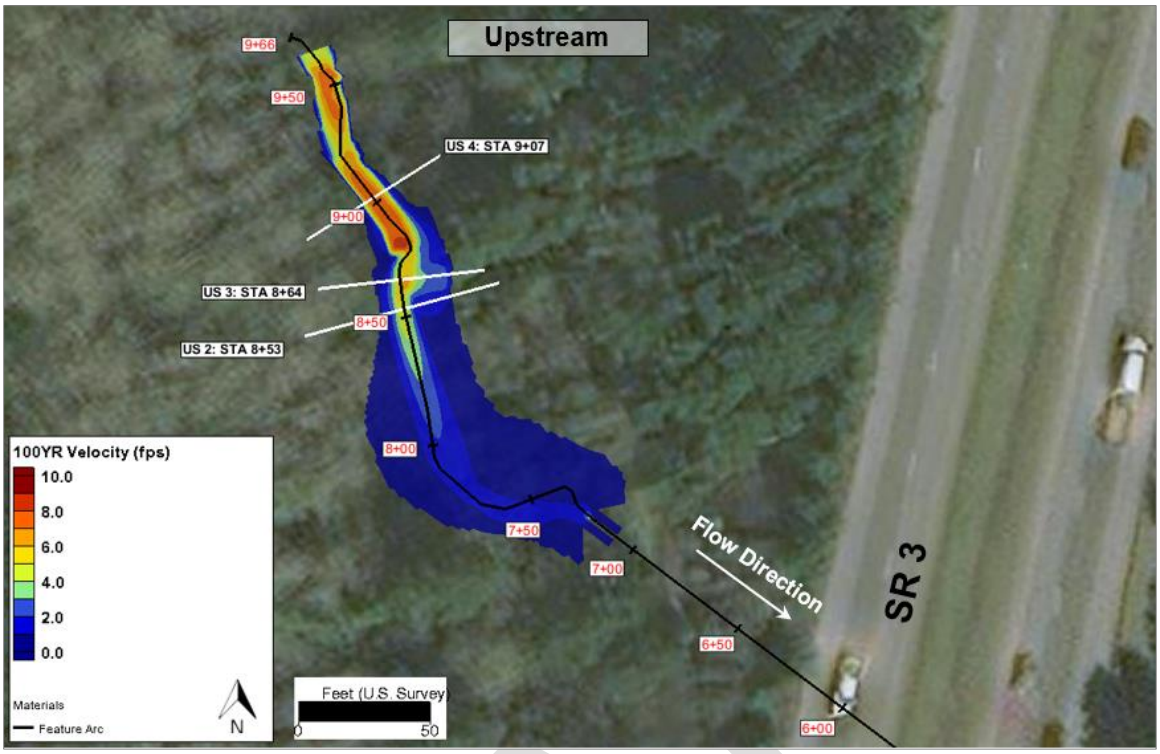

Figure 49: Existing-conditions 100-year velocity map with cross section locations

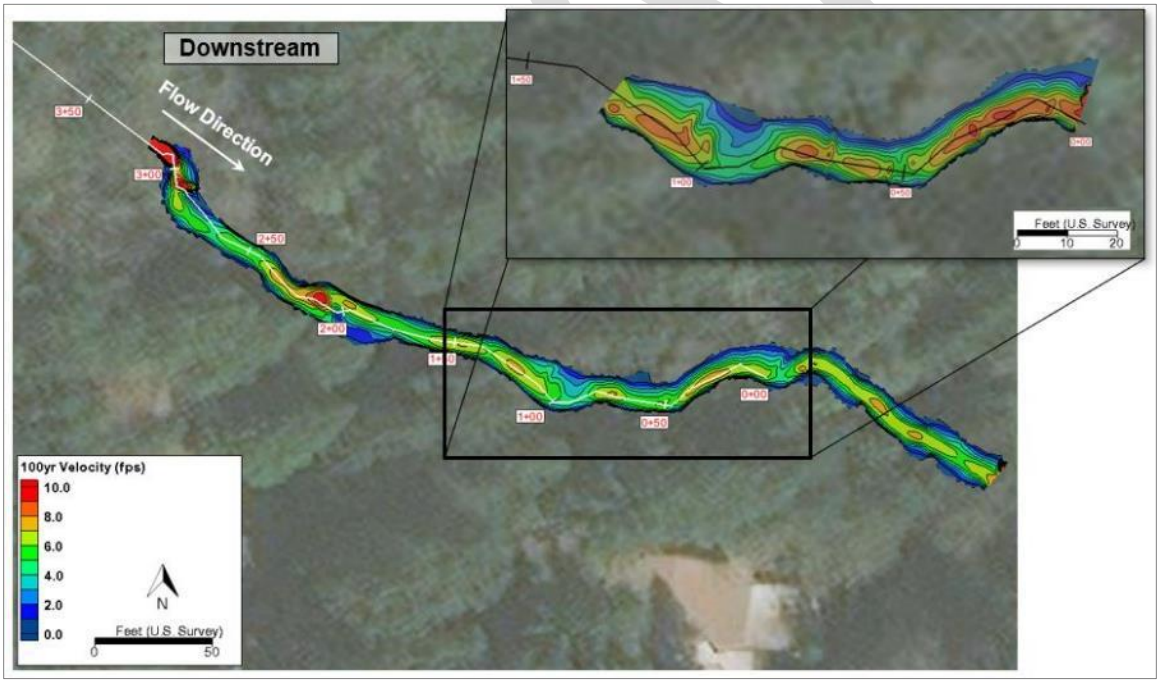

Figure 50: Existing-conditions 100-year velocity map with cross section locations

Table 14: Existing-conditions average channel and floodplain velocities

Cross section location	Q100 average velocities tributary scenario (fps)		
	LOB[a]	Main channel	ROB[a]
US 4: STA 9+07	3.7	7.5	2.7
US 3: STA 8+64	3.1	5.6	1.3
US 2: STA 8+53	1.3	3.9	1.8
Structure	NA	NA	NA
DS 3: STA 2+47	1.3	6.1	3.0
DS 11: STA 1+20	2.8	6.4	4.5
DS 13: STA 0+74	3.8	7.6	3.4

a. Right overbank (ROB)/left overbank (LOB) locations were approximated based on the surveyed grade break located at the observed top of bank.

5.3 Natural Conditions

A natural conditions model was not required as the system is confined, as noted in Section 2.7.2.1.

5.4 Proposed Conditions: 20-Foot Minimum Hydraulic Width

The hydraulic width is defined as the width perpendicular to the channel beneath the proposed structure that is necessary to convey the design flow and allow for natural geomorphic processes. The hydraulic modeling assumes vertical walls at the edge of the minimum hydraulic width unless otherwise specified. Section 4.2.2 provides a description of how the minimum hydraulic width was determined.

The proposed-conditions model provided results for the 2-year; 100-year; 500-year; and projected 2080, 100-year MRIs. The proposed step-pool design spaced at 20-foot increments was modeled for the uppermost sequence of four step-pools, shown on Figure 51, Figure 52, and Figure 53. The larger-flow scenarios, greater than and equal to the 100-year event, do not include the 12- to 18-inch-high steps as the channel-spanning wood is intended to be mobile at these higher-flow events. Further modeling refinement will be required at future stages of the design. The remaining proposed grading was simplified with a constant slope until its terminus near the existing outlet. Table 15 summarizes the hydraulic results.

The proposed step-pool design performs similar to the observed step-pool morphology in the reference reach in regard to velocity distribution and depth, shown on Figure 54. Model results indicate 100-year velocity range from 6.0 to 6.5 fps in the pool to 8.7 to 9.4 fps over the step, similar to the reference reach. Allowing the wood steps to be mobile at high flows keeps velocities from peaking above 10 fps while also providing refugia at low flows. Other hydraulic metrics at STA 7+22 (Figure 55), shown in Table 15, are within the range of observed values in the reference reach at DS 11 STA 1+20 and DS 13 STA 0+74. The spatial distribution of upstream and downstream velocity at the 100-year event is shown in plan view on Figure 56 and Figure 57, respectively, and tabulated in Table 16. Additional existing-conditions model results is in Appendix H.

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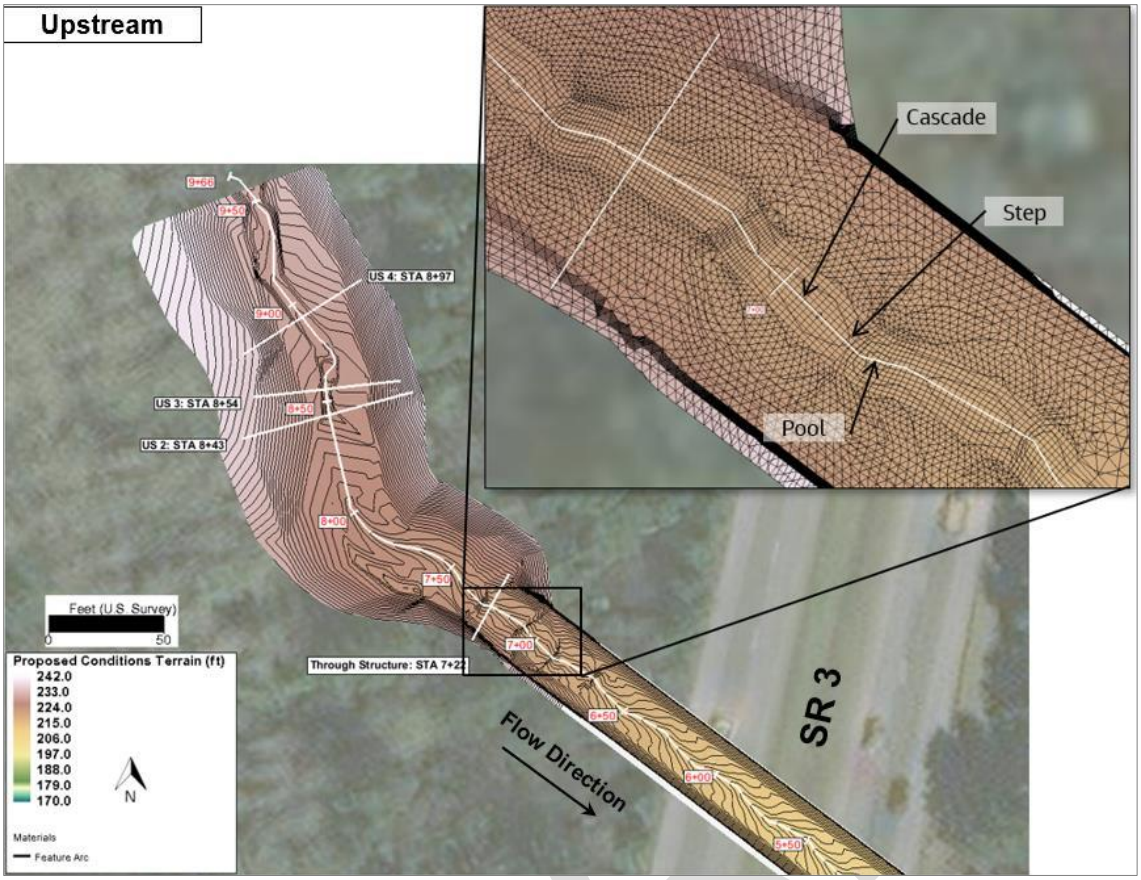

Figure 51: Locations of cross sections on upstream portion of proposed alignment used for results reporting.

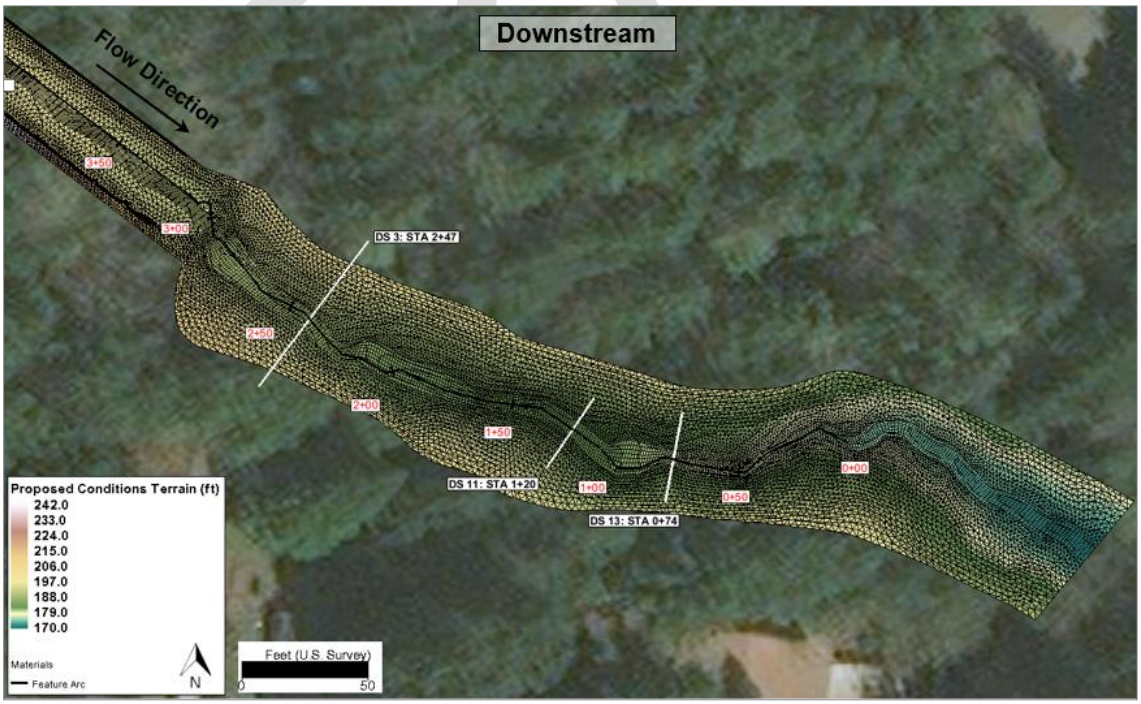

Figure 52: Locations of cross sections on downstream portion of proposed alignment used for results reporting.

Table 15: Average main channel hydraulic results for proposed conditions

Hydraulic parameter	Cross section	2-year	100-year	Projected 2080, 100-year	500-year
Average WSE (ft)[a]	**US 4**: 9+07	229.2	229.9	230.2	230.0
	US 3: 8+64	228.1	228.7	229.0	228.8
	US 2: 8+53	228.0	228.5	228.9	228.7
	Through Structure 7+22	223.1	223.7	224.0	223.7
	DS 3: 2+47	188.6	189.8	190.3	189.9
	DS 11: 1+20	182.2	182.9	183.3	183.0
	DS 13: 0+74	180.0	181.1	181.6	181.2
Maximum depth (ft)[a]	**US 4**: 9+07	0.8	1.6	1.9	1.7
	US 3: 8+64	1.4	2.1	2.3	2.1
	US 2: 8+53	2.1	2.8	3.1	2.9
	Through Structure 7+22	0.6	1.3	1.6	1.4
	DS 3: 2+47	1.3	2.6	3.1	2.8
	DS 11: 1+20	0.8	1.5	1.9	1.6
	DS 13: 0+74	0.9	1.9	2.5	2.1
Average velocity (fps)	**US 4**: 9+07	4.0	4.7	4.7	4.6
	US 3: 8+64	2.4	3.0	3.7	3.2
	US 2: 8+53	0.7	1.9	2.7	2.2
	Through Structure 7+22	3.0	5.4	6.4	5.9
	DS 3: 2+47	3.8	4.7	5.4	5.1
	DS 11: 1+20	4.3	6.1	6.9	6.4
	DS 13: 0+74	4.7	5.1	5.8	5.3
Average shear (lb/sf)	**US 4**: 9+07	1.2	1.8	2.2	1.9
	US 3: 8+64	0.5	1.7	2.5	1.9
	US 2: 8+53	0.1	0.5	1.0	0.6
	Through Structure 7+22	1.6	4.1	5.6	4.9
	DS 3: 2+47	1.0	1.6	2.7	2.0
	DS 11: 1+20	1.5	3.4	4.6	3.7
	DS 13: 0+74	1.8	3.0	4.2	3.4

a. Rounding can create perceived differences when comparing changes to Average WSE and maximum depth, up to +/-0.2 feet.

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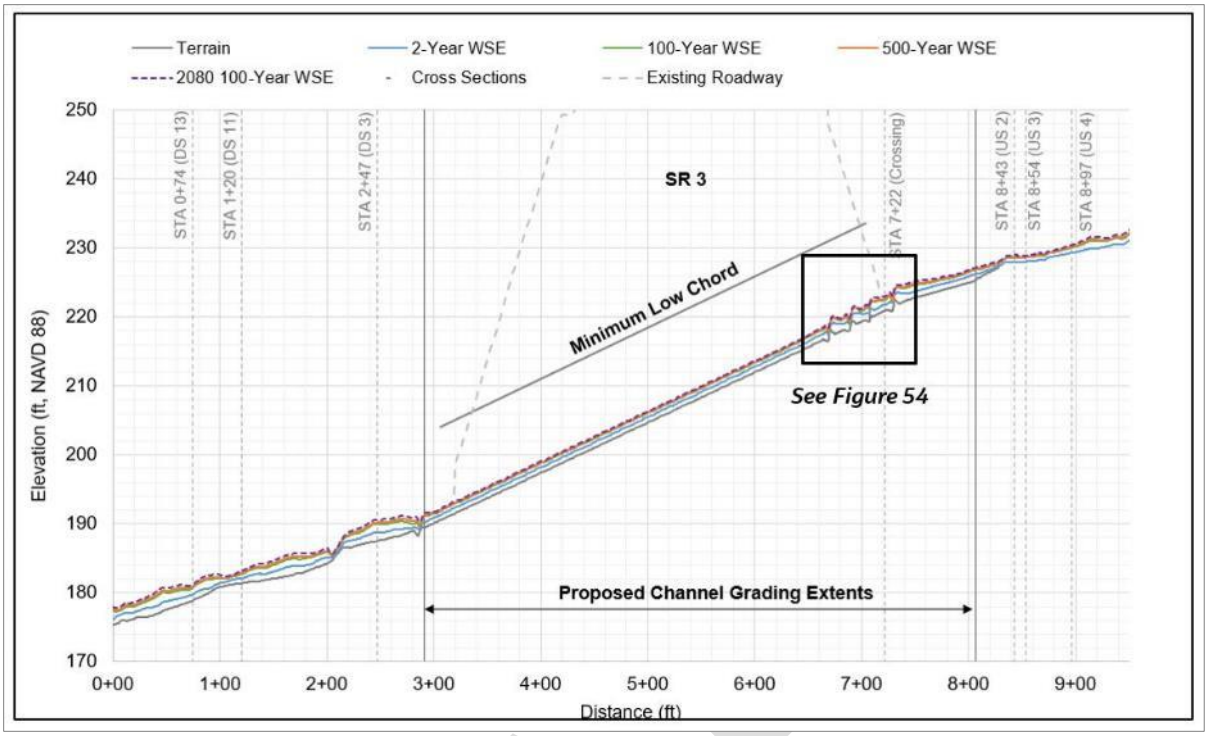

Figure 53: Proposed-conditions water surface profiles

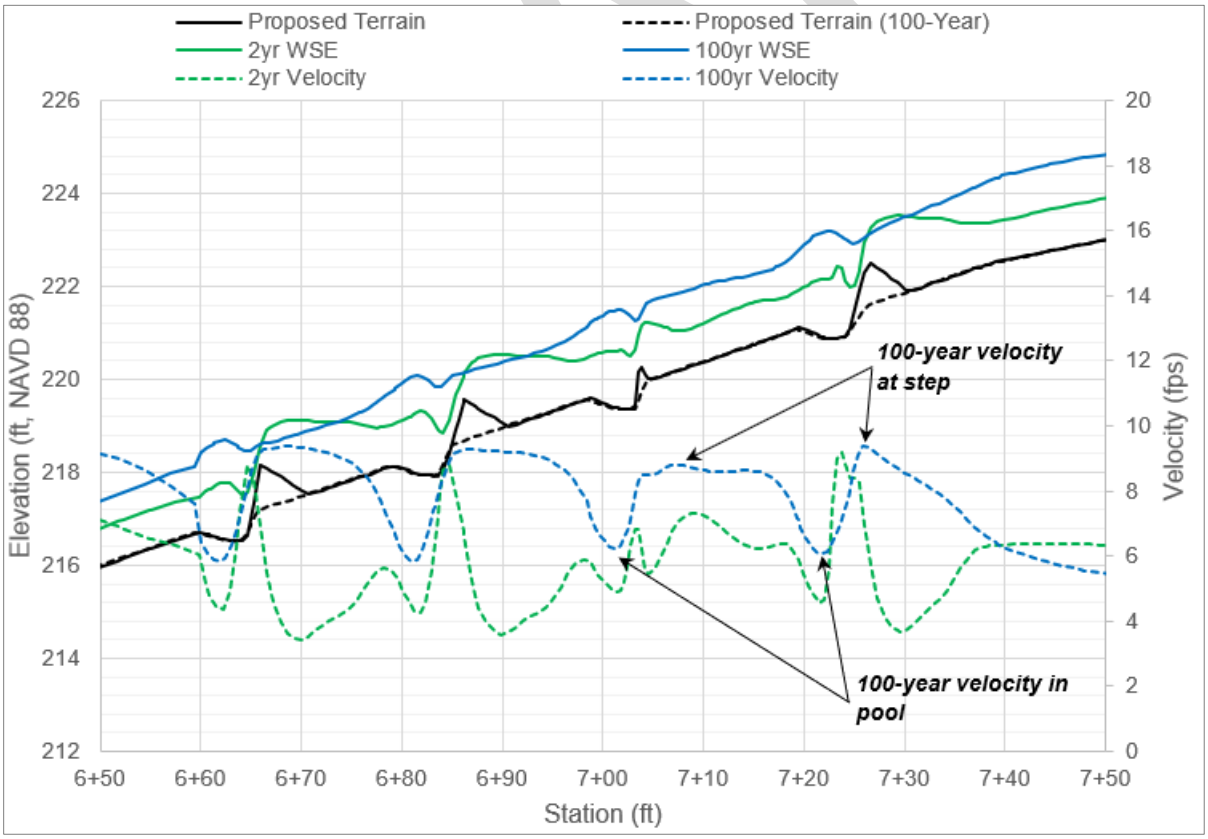

Figure 54: Proposed-conditions water surface profiles at step pools

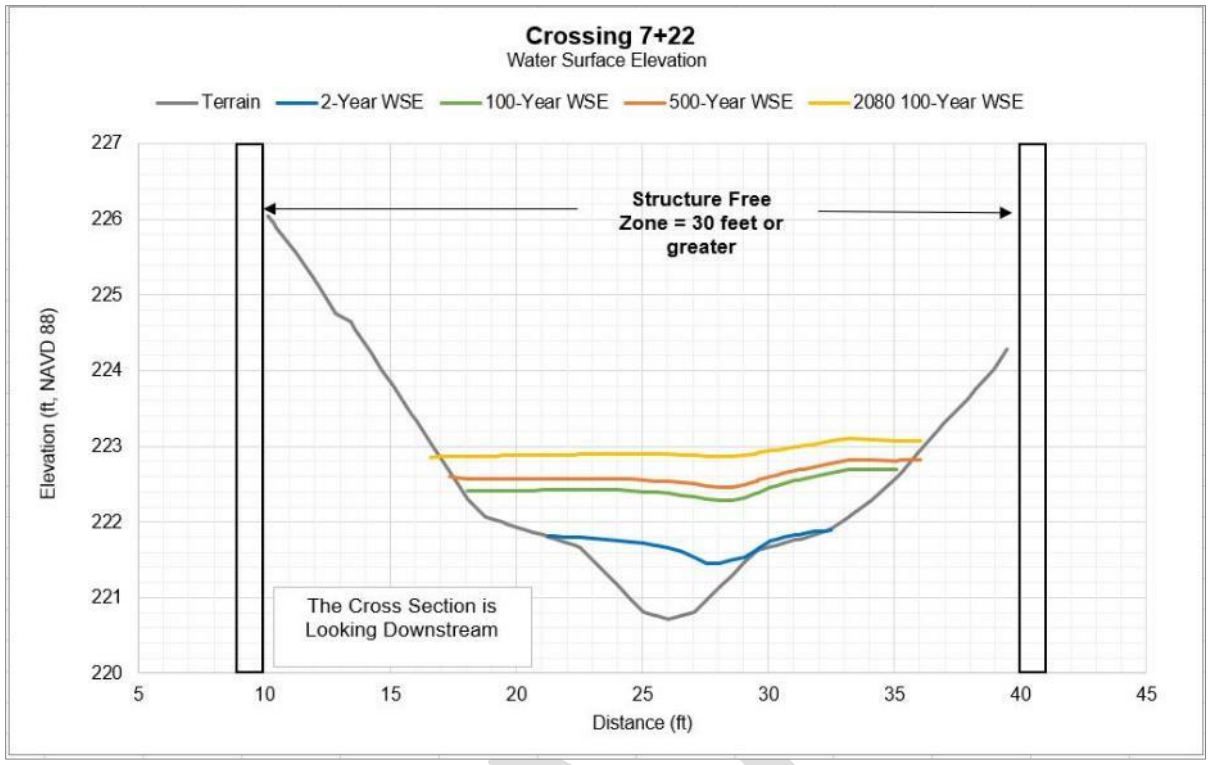

Figure 55: Typical section through proposed structure (STA 7+22)

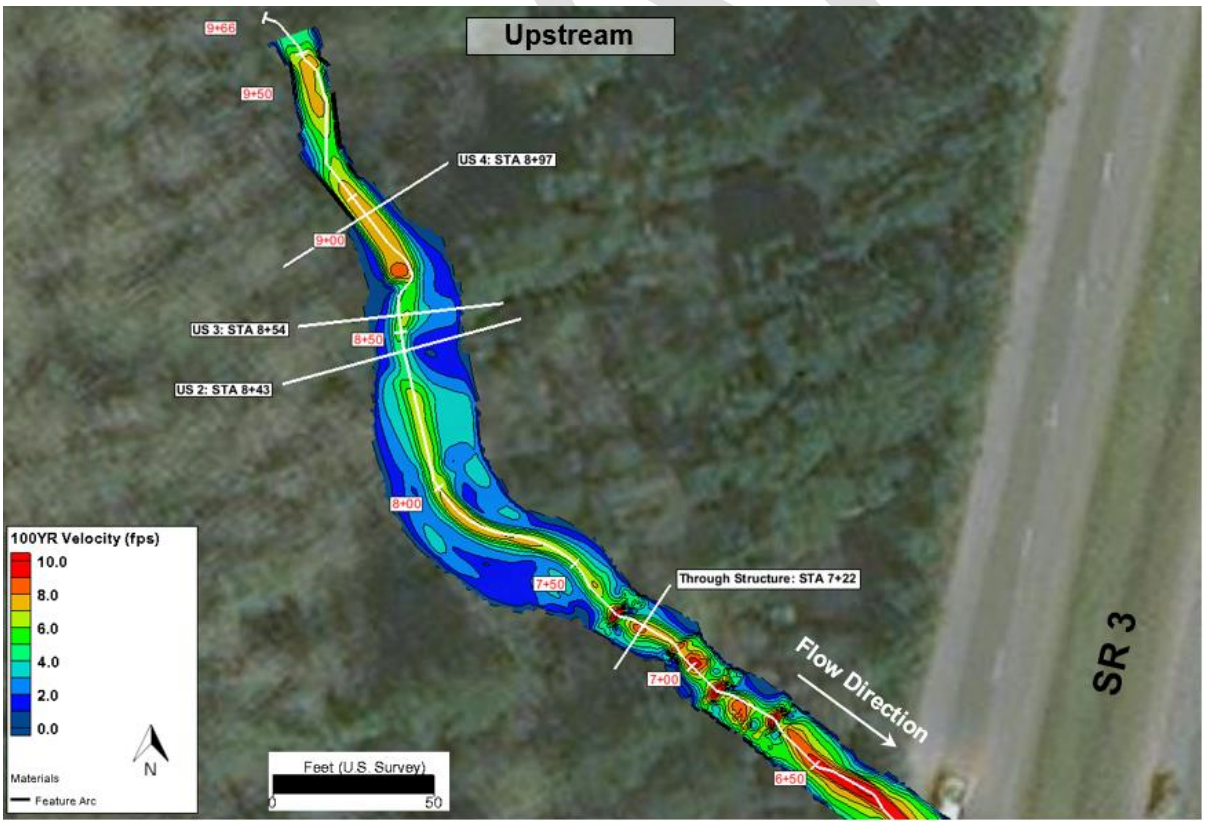

Figure 56: Proposed conditions upstream 100-year velocity map

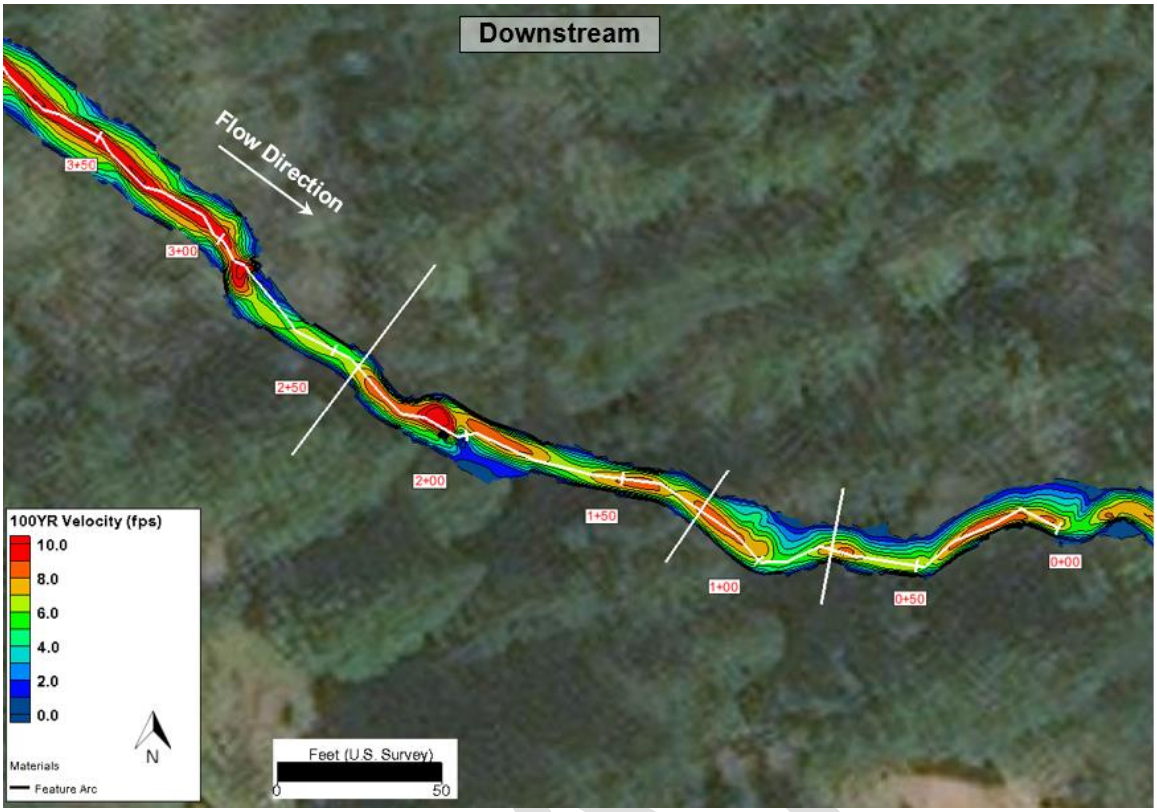

Figure 57: Proposed conditions downstream 100-year velocity map

Table 16: Proposed conditions average channel and floodplains velocities

Cross section location	Q100 average velocities (fps)			2080 Q100 average velocity (fps)		
	LOB[a]	Main channel	ROB[a]	LOB[a]	Main channel	ROB[a]
DS 13: STA 0+74	3.3	7.1	3.5	4.4	7.9	4.5
DS 11: STA 1+20	3.9	7.7	3.1	5.1	8.7	4.1
DS 3: STA 2+47	1.3	6.0	2.6	2.6	7.2	3.9
Through Structure: STA 7+22	NA	5.4	NA	NA	6.4	NA
US 2: STA 8+53	1.3	3.7	1.9	2.3	4.2	2.3
US 3 STA 8+64	3.0	5.5	1.2	4.1	6.2	1.2
US 4: STA 9+07	3.3	7.4	2.5	3.8	8.8	2.6

a. ROB/LOB locations were approximated based on the surveyed grade break located at the observed top of bank.

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6 Floodplain Evaluation

This project is not within a FEMA special flood hazard area but rather in a Zone X area of minimal flood hazard (FEMA 2017); see Appendix A for FIRMette. The existing and proposed conditions were evaluated to determine whether the project would cause a change in flood risk.

6.1 Water Surface Elevations

Generally, WSEs decrease across the model domain when comparing the existing and proposed conditions. Figure 58 shows the water surface profile, comparing the 100-year MRI results for existing and proposed conditions. When looking at the water surface profile, the existing and proposed WSEs converge approximately 120 feet upstream and 50 feet downstream of the existing crossing. The existing and proposed alignments are offset by 10 feet upstream of the crossing due to the additional proposed channel length, this is visible in the water surface profiles upstream of STA 8+50.

Figure 59 shows a comparison of the existing and proposed model results at the 100-year MRI. This figure shows that there is a small area of water surface rise, roughly 1 foot above existing conditions at the current outlet. This occurs because the existing conditions outlet is characterized by high velocity and low water depth, the proposed condition has slower velocity and greater flow depth. This water surface rise is localized and returns to a reduction in WSE within 25 feet of the outlet.

The changes in WSE and inundation areas do not pose a risk to properties or infrastructure. A flood risk assessment will be developed during later stages of the design.

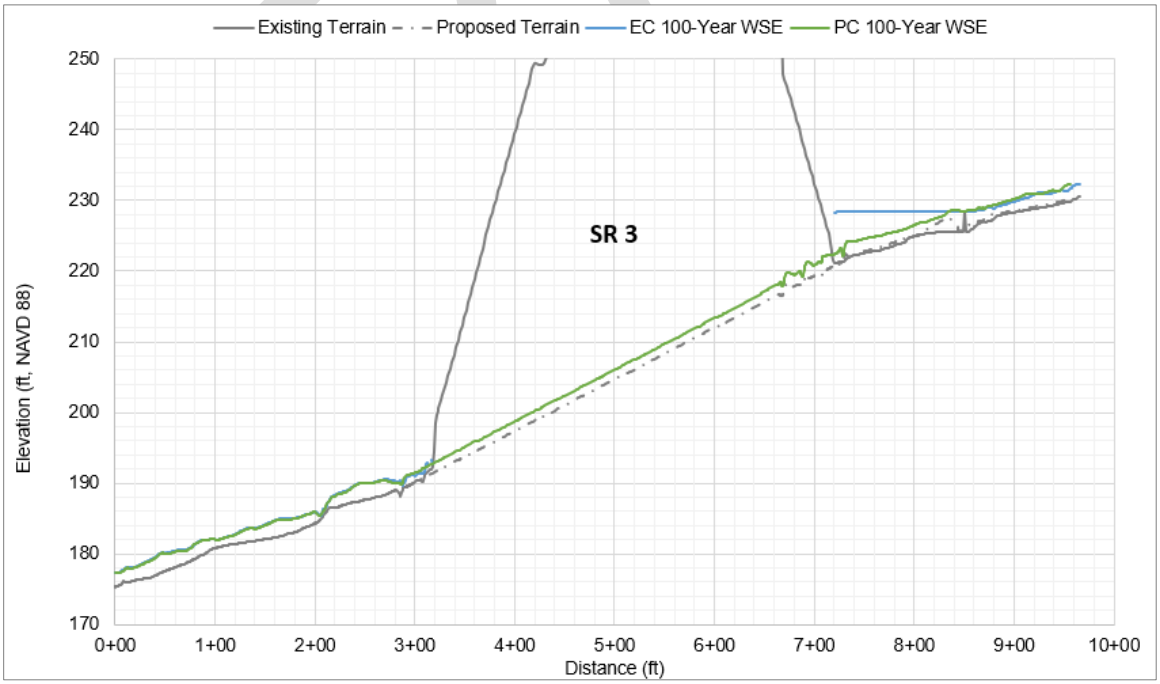

Figure 58: Existing- and proposed-conditions 100-year water surface profile comparison along the proposed alignment.

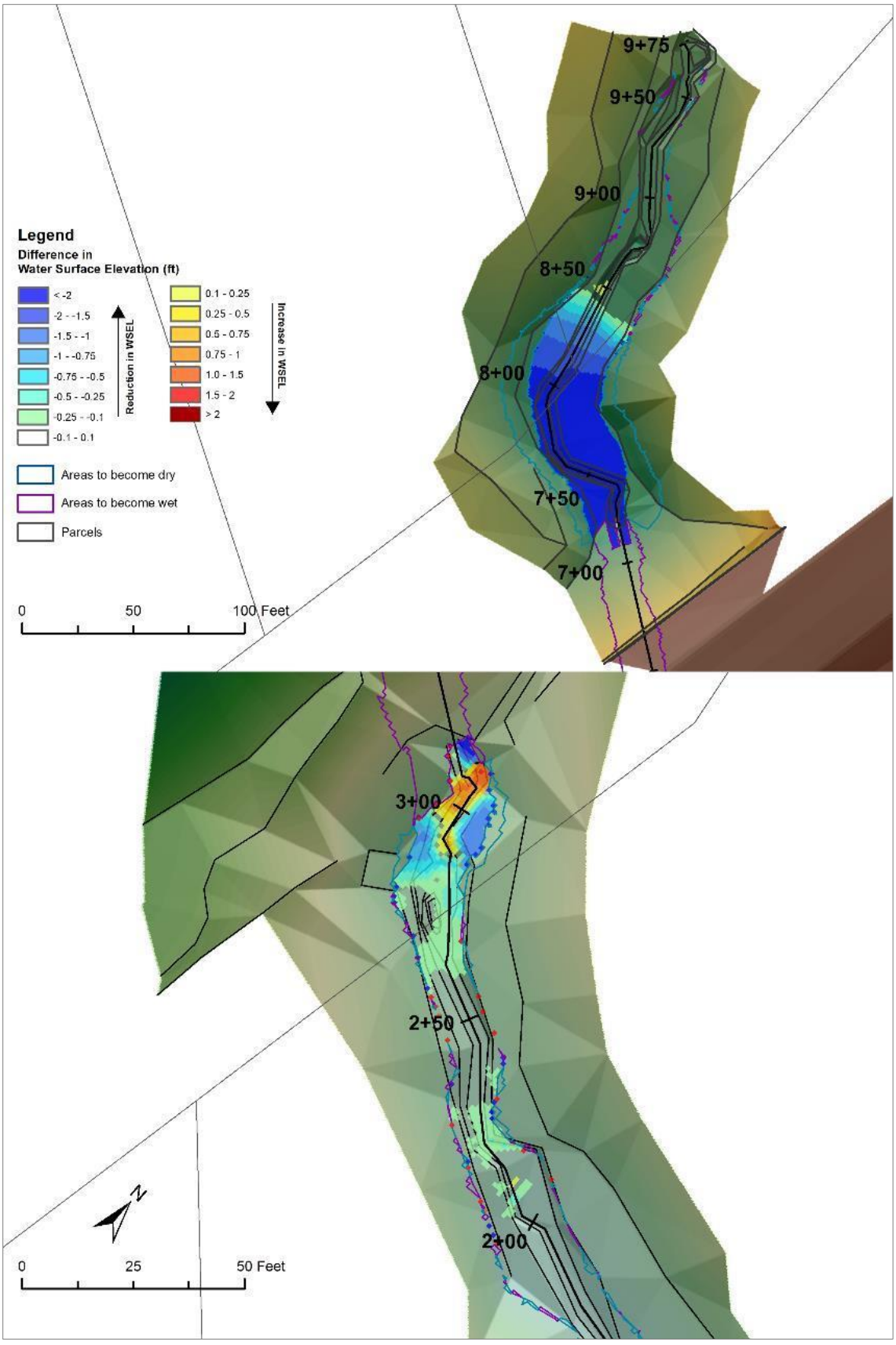

Figure 59: 100-year WSE change from existing to proposed conditions

7 Scour Analysis

For this preliminary phase of the project, the risk for lateral migration, potential for long-term degradation, and evaluation of preliminary total scour is based on available data, including but not limited to the geotechnical scoping memorandum (WSDOT 2021b), Wolman pebble counts (Section 2.7.3), and the proposed channel design concept (Appendix D). This evaluation is to be considered preliminary and is not to be taken as a final recommendation.

Using the results of the hydraulic analysis (Section 5.4), based on the recommended minimum hydraulic opening (20 feet) and considering the potential for lateral channel migration, preliminary scour calculations for the scour design flood (2080, 100-year event; 138 cfs) and scour check flood (2080, 100-year event) were performed following the procedures outlined in *Evaluating Scour at Bridges* (HEC-18) (Arneson et al. 2012). HQ Hydraulics has determined that the projected 2080, 100-year event shall be incorporated into the design. Additionally, the design team analyzed the 500-year (100 cfs) and 2-year (21 cfs) events to investigate how other discharges, particularly lower flows, influence scour at the site.

Scour components considered in the analysis include the following:

- Long-term degradation
- Contraction scour
- Local scour

In addition to the three scour components listed above, the potential for lateral migration was assessed to evaluate total scour at the proposed highway infrastructure. These various scour components are discussed in the following sections.

7.1 Lateral Migration

The risk of lateral migration is moderate. Lateral migration may be triggered by either hydraulic roughness of the proposed channel driving flow to a hydraulically smooth floodplain or reactivation of existing mass-wasting landforms introducing a sediment pulse to the channel. A sediment pulse could create transport-limited conditions, where more sediment is available to transport than the capacity to move sediment. Deposition could also occur because the 4 percent slope reach just upstream of the crossing is downstream of a 6 to 7 percent slope reach (Figure 23). A decrease in transport capacity could result in deposition. One potential channel response to this condition is a change in alignment via migration or avulsion. However, the potential for lateral migration could be reduced with the LWM structures placed upstream of the crossing (Figure 28); this will be evaluated at later design stages.

7.2 Long-term Degradation of the Channel Bed

The risk of both degradation and aggradation is moderate at this site. The risk of degradation may be caused by the flatter 4 percent slope reach immediately upstream of the proposed channel. The proposed crossing is on a 7 percent grade; this has been agreed upon by comanagers in lieu of extensive grading upstream of the crossing. As such, there is a risk that stored sediment in the 4 percent slope reach may mobilize over time. The geotechnical scoping

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memorandum (WSDOT 2021b) indicates that soils through the proposed crossing are cohesionless and are highly erodible. No scour-resistant materials were observed in the borehole drillings. The depth of degradation could be up to 7 feet at the structure inlet (Figure 60). The design team did not observe any base level controls during the site visits; the base control for the potential degradation profile (Figure 60) is at the downstream crossing of Ptarmigan Lane NW (WDFW ID 991905). Per Section 2.7.4., acute, ongoing incision was not observed in the existing channel.

This degradation risk, however, could be offset by the risk of aggradation. Upstream of the crossing, extensive mass-wasting deposits have been mapped (Figure 5). These deposits represent a sediment source that may remain in storage or be periodically mobilized at higher flows. The slope upstream and through the structure can be excepted to amalgamate from its present character of discrete transitions over time. The averaged slope for this reach is 5.7 percent.

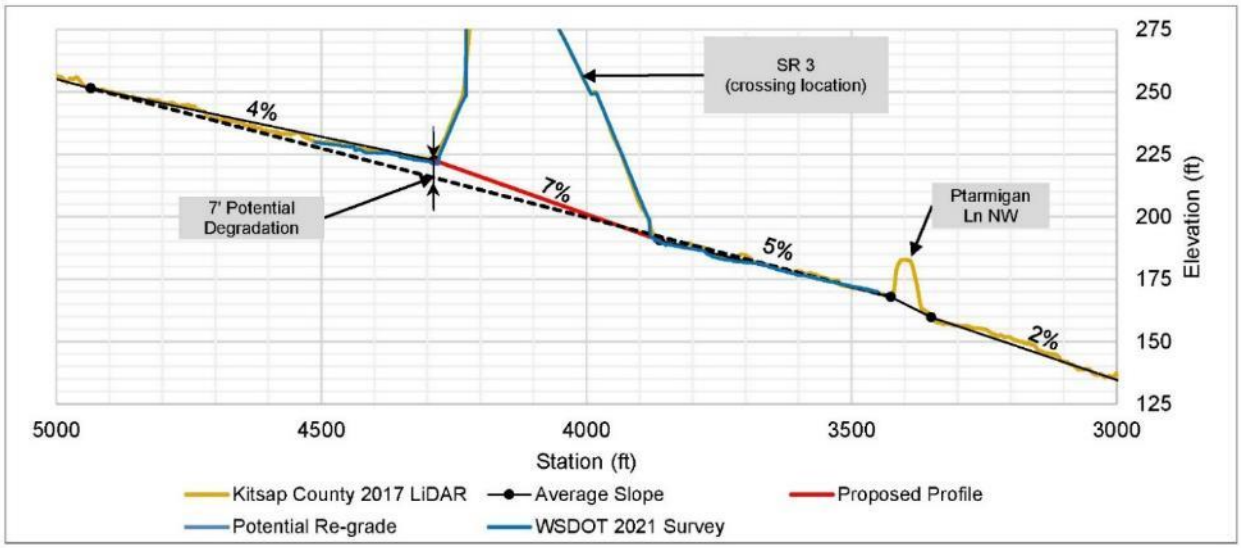

Figure 60: Potential long-term degradation at the proposed structure upstream face

As described in Section 4.3.2.1, some elements of the conceptual wood-forced step-pool design are anticipated to remain stable up to and through the 100-year event, while other pieces are only stable up to and through the 25-year event. Localized scour in the cascade or pool reaches of the profile will likely occur; however, the structure of the steps and pools will be anchored by 1- and 2-man boulders, see Appendix D for stream plan sheets. These step-pool features would likely provide some stability and bed protection from vertical degradation, but this protection was not considered in this scour analysis. The maximum anticipated long-term degradation depth of 7 feet has been adopted at this phase of the design.

7.3 Contraction Scour

Main channel contraction scour was evaluated through the proposed crossing and computed following guidance from HEC-18 (Arneson et al. 2012). Live bed conditions prevail in the main channel; however, following HEC-18 guidance, the design team computed both live bed and clear water conditions. The particle diameters used in the clear water equation are based on the average particle size diameters of the surface pebble counts collected in the field (see Table 5

in Section 2.7.3), a D_{50} of 20.3 millimeters. Borehole data (WSDOT 2021b) was considered, but ultimately not used for scour analysis as the D_{50} (0.238 millimeters) was drastically smaller than the surface pebbles.

The borehole sample was taken at an elevation of 245 feet, which is above the proposed channel bed elevation through the crossing (190.5 to 219.6 feet). However, the sample was taken within the same Engineering Stratigraphic Unit as the sample, indicating that it has similar properties. The width transporting sediment for both the approach and contracted sections for the live bed condition were defined based on the Critical Velocity Index (CVI) map (see Figure 61). The CVI was derived from a modified version of Equation 6.1 from HEC-18 and relates stream velocity to the mobility of the D_{50} of the streambed material (Arneson et al. 2012). Values over 1.0 on the CVI generally relate to live-bed scour conditions.

The 2080, 100-year CVI boundary aligns well with the main channel bank topography through the crossing and is a reasonable estimate of the main channel width. The approach arc was placed at a location upstream of the crossing where representative hydraulics not influenced by the crossing prevail. The total width that is transporting sediment through the approach section is 9.4 feet, while the contracted arc main channel width is 16.5 feet. The main channel live bed contraction scour results in 0.6 feet of predicted scour for the scour design and scour check flood events (Figure 62). Live bed contraction scour for the 2-year event resulted in no general contraction scour, the 500-year event resulted in 0.5 feet of scour. These results support the assertion that larger discharge events generate more scour, and no additional discharges between the 2-year; 500-year; and 2080, 100-year events were investigated.

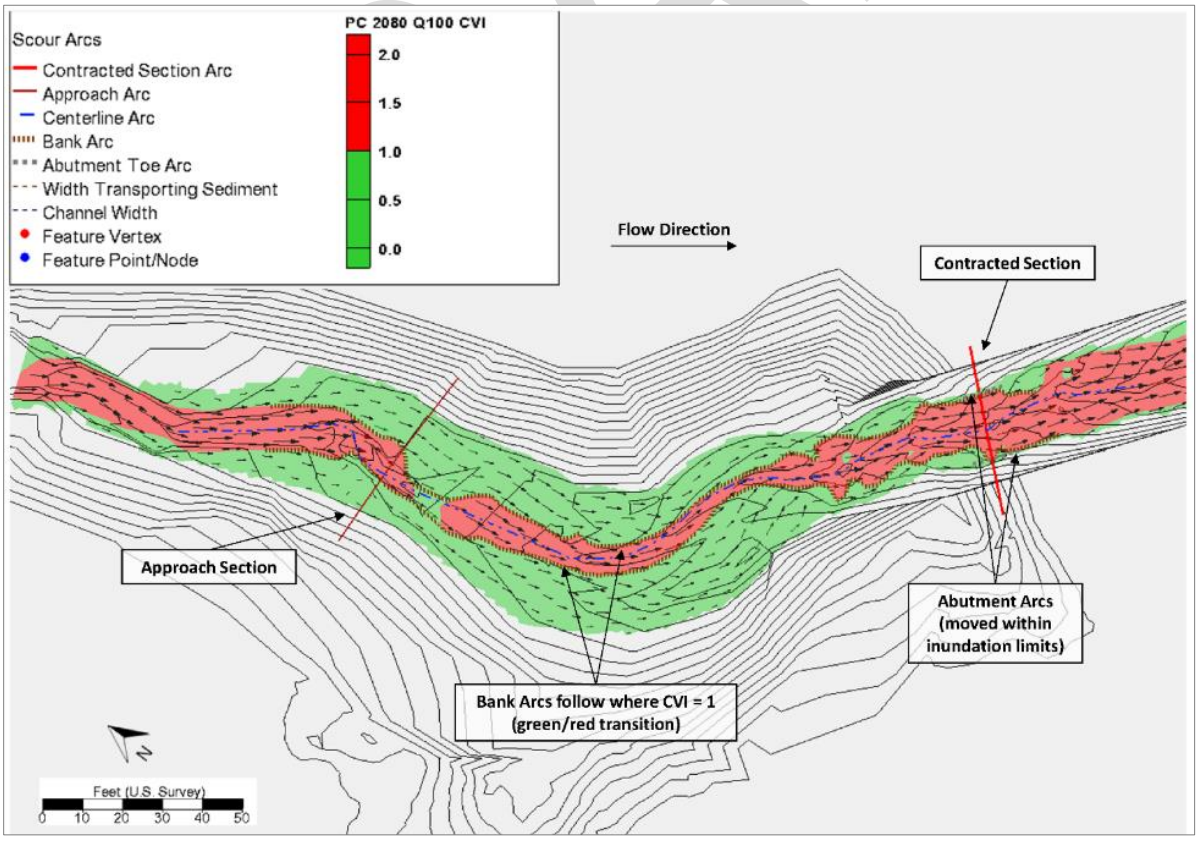

Figure 61: Location of bridge scour coverage arcs at the structure inlet

Computation Method: Clear-Water and Live-Bed Scour

Parameter	Value	Units	Notes
Input Parameters			
Average Depth Upstream of Contraction	1.49	ft	
D50	20.330160	mm	0.2 mm is the lower li...
Average Velocity Upstream	6.24	ft/s	
Results of Scour Condition			
Critical velocity above which bed material of siz...	4.84	ft/s	
Contraction Scour Condition	Live Bed		
Live Bed & Clear Water Input Parameters			
Temperature of Water	60.00	ºF	
Slope of Energy Grade Line at Approach Section	0.204893	ft/ft	
Discharge in Contracted Section	135.98	cfs	
Discharge Upstream that is Transporting Sediment	87.37	cfs	
Width in Contracted Section	16.55	ft	Remove widths occupie...
Width Upstream that is Transporting Sediment	9.43	ft	
Depth Prior to Scour in Contracted Section	0.97	ft	
Unit Weight of Water	62.40	lb/ft^3	
Unit Weight of Sediment	165.00	lb/ft^3	
Results of Clear Water Method			
Diameter of the smallest nontransportable partic...	25.412700	mm	
Average Depth in Contracted Section after Scour	1.59	ft	
Scour Depth	0.63	ft	Negative values imply '...
Results of Live Bed Method			
k1	0.640000		
Shear Velocity	3.13	ft/s	
Fall Velocity	1.64	ft/s	
Average Depth in Contracted Section after Scour	1.57	ft	
Scour Depth	0.61	ft	Negative values imply '...
Shear Applied to Bed by Live-Bed Scour	0.4593	lb/ft^2	
Shear Required for Movement of D50 Particle	0.2669	lb/ft^2	
Recommendations			
Recommended Scour Depth	0.61	ft	Negative values imply '...

Figure 62: Results for main channel live bed contraction scour

7.4 Local Scour

The following sections describe the scour methodology and results for the different local scour components included within this crossing.

7.4.1 Pier Scour

The crossing will not have piers and therefore pier scour was not calculated.

7.4.2 Abutment Scour

Abutment scour was estimated using the National Cooperative Highway Research Program (NCHRP) 24-20 approach for the scour design flood and scour check flood. Abutments were assumed to be vertical walls for the calculations. Modeled results for scour design event do not interact with the structure abutments. However, based on the potential for lateral migration, scour condition Type A main channel hydraulics was considered applicable for all flows examined. Left and right bank abutment scour was analyzed, resulting in a maximum of 0 feet of predicted scour below the thalweg along both abutments for the scour design event and scour check flood event. The hydraulic toolbox results for abutment scour at the left abutment wall are shown on Figure 63.

Computation Method: NCHRP

Parameter	Value	Units	Notes
Input Parameters			
Scour Condition	Compute		
Scour Condition Location	Type a (Main Ch...		
Abutment Type	Vertical-wall abu...		
Unit Discharge, Upstream in Main Channel (q1)	9.26	cfs/ft	
Unit Discharge in Constricted Area (q2)	8.58	cfs/ft	
D50	20.330160	mm	0.2 mm is the lower limit f...
Upstream Flow Depth	1.49	ft	
Define Shear Stress of Floodplain	☐		
Flow Depth prior to Scour	1.71	ft	Depth at Abutment Toe
Results			
q2 / q1	0.93		
Average Velocity Upstream	6.24	ft/s	
Critical Velocity above which Bed Materal of Size...	4.84	ft/s	
Scour Condition	Live Bed		
Scour Condition	a (Main Channel)		
Amplification Factor	1.20		
Flow Depth including Contraction Scour	1.39	ft	
Scour depth from Long-Term Degradation calcul...	0.00	ft	
Maximum Flow Depth including Abutment Scour	1.67	ft	Including the long-term sc...
Scour Hole Depth	-0.04	ft	Negative values imply 'zer...
Scour Hole			
Angle of Repose	38.00	degr...	
Ratio of Bottom Width of Scour Hole to Scour Ho...	0.00		1.0 means the bottom wid...

Figure 63: Hydraulic toolbox results for left bank abutment scour associated with the 2080, 100-year event (scour design and scour check flood event)

7.4.3 Bend Scour

Bend scour was not quantified at this crossing given the lack of anticipated bends in the vicinity of the crossing.

7.5 Total Scour

Table 17 provides calculated total scour depths for the proposed SF Johnson Creek structure. Total scour is estimated to be 7.6 feet during the scour design and check floods and is located near the structure inlet. The recommended scour depth should be maintained throughout the length of the crossing. No structure type has been recommended by WSDOT HQ Hydraulics.

Table 17: Calculated scour analysis summary for SR 3 at SF Johnson Creek

Scour Condition	Contracted Section of SR 3 Structure[a,b]	
	Design and Check Flood Event 2080, 100-year	500-year
Long-Term Degradation (feet)	7.0	7.0
Contraction Scour (feet)	0.6	0.5
Local Abutment Scour (feet)	0.0	0.0
Total Depth of Scour (feet)[c]	**7.6**	**7.5**

a. Contracted section location is shown on Figure 61.
b. Depths relative to the proposed thalweg depth.
c. Depths do not include geotechnical requirements for any additional depth below the calculated scour.

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8 Scour Countermeasures

The need for scour countermeasures has not yet been determined. If scour countermeasures are needed, they will be placed between the structure free zone and the minimum hydraulic opening. The minimum hydraulic opening, as described in Section 4.2, is 20 feet and the structure free zone is 30 feet. Figure 64 is a copy of Figure 7-8 from WSDOT's *Hydraulics Manual* (2022), showing a conceptual layout for when scour countermeasures are needed, given the presence of abutment scour.

Figure 7-8 Scour Countermeasure Design for Water Crossing Structures with Deep Foundation and Calculated Abutment Scour

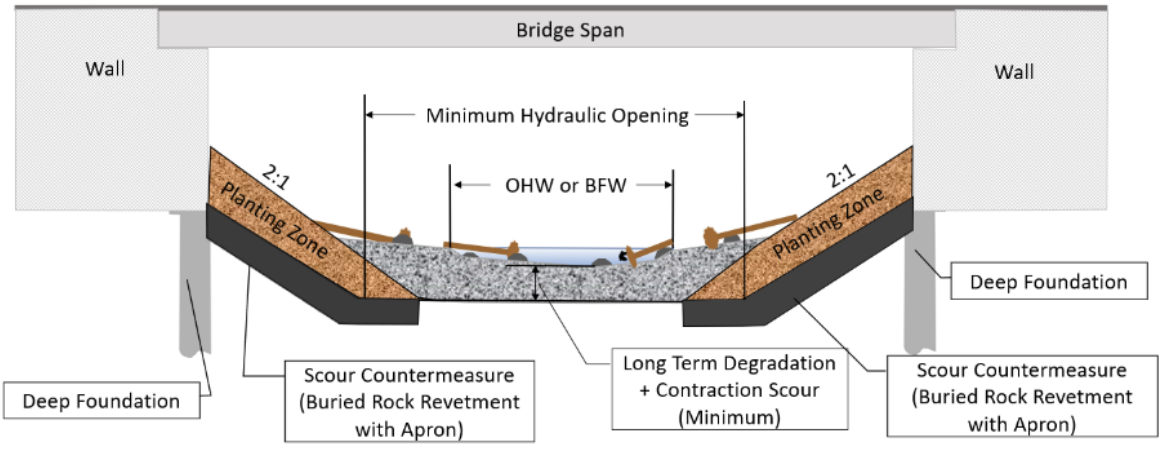

Figure 64: Conceptual diagram of scour countermeasures (WSDOT 2022, p. 7-29)

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9 Summary

Table 18 presents a summary of the results of this PHD report.

Table 18: Report summary

Stream crossing category	Element	Value	Report location
Habitat gain	Total length	5,367 LF	1 Introduction
Bankfull width	Reference reach found?	Yes	2.7.1 Reference Reach Selection
	Design BFW	7-9 ft	2.7.2 Channel Geometry
	Concurrence BFW	7-9 ft	2.7.2 Channel Geometry
Floodplain utilization ratio (FUR)	Flood-prone width	11.7 ft	2.7.2.1 Floodplain Utilization Ratio
	Average FUR	US = 3.6 DS = 1.6	2.7.2.1 Floodplain Utilization Ratio
Channel morphology	Existing	Step-pool	2.7.2 Channel Geometry
	Proposed	Step-pool	4.3.2 Channel Complexity
Hydrology/design flows	100 yr flow	85 cfs	3 Hydrology and Peak Flow Estimates
	2080, 100 yr flow	138 cfs	3 Hydrology and Peak Flow Estimates
	2080, 100 yr used for design	Yes	3 Hydrology and Peak Flow Estimates
	Dry channel in summer	No	2.4 Fish Presence in the Project Area
Channel geometry	Existing	Trapezoidal	2.7.2 Channel Geometry
	Proposed	Trapezoidal	4.1.2 Channel Planform and Shape
Channel slope/gradient	Existing culvert	7.1%	2.1 Site Description
	Reference reach	6.6%	2.7.1 Reference Reach Selection
	Proposed	7.3%	4.1.1 Channel Gradient
Hydraulic width	Existing	3 ft	1 Introduction
	Proposed	MHO = 20 ft SFZ = 30 ft or greater	4.2.2 Hydraulic Width
	Added for climate resilience	No	4.2.2 Hydraulic Width
Vertical clearance	Required freeboard	3 ft	4.2.3 Vertical Clearance
	Required freeboard applied to 100 yr or 2080, 100 yr	2080, 100 yr	4.2.3 Vertical Clearance
	Maintenance clearance	Required 10 ft	4.2.3 Vertical Clearance
	Low chord elevation	US = 233.5 DS = 204.0	4.2.3 Vertical Clearance
Crossing length	Existing	400 ft	2.6.2 Existing Conditions
	Proposed	400 ft	4.2.4 Hydraulic Length
Structure type	Recommendation	Yes	4.2.6 Structure Type
	Type	Bottomless, three-sided structure	4.2.6 Structure Type
Substrate	Existing	D_{50} = 0.8 in	2.7.3 Sediment
	Proposed	$D_{50\ (Bathurst)}$ = 4.6 in $D_{50(MCSS)}$ = 3.7 in	4.3.1 Bed Material
	Coarser than existing?	Yes	4.3.1 Bed Material

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Stream crossing category	Element	Value	Report location
Channel complexity	LWM for bank stability	No	4.3.2 Channel Complexity
	LWM for habitat	Yes	4.3.2 Channel Complexity
	LWM within structure	Yes	4.3.2 Channel Complexity
	Meander bars	0	4.3.2 Channel Complexity
	Boulder clusters	0	4.3.2 Channel Complexity
	Coarse bands	0	4.3.2 Channel Complexity
	Steps	Yes	4.3.2.3 Step-Pool Design Details
	Mobile wood	Yes	4.3.2 Channel Complexity
Floodplain continuity	FEMA mapped floodplain	No	6 Floodplain Evaluation
	Lateral migration	Yes	2.7.5 Channel Migration
	Floodplain changes?	Yes	6 Floodplain Evaluation
Scour	Analysis	Determined at FHD	7 Scour Analysis
	Scour countermeasures	Determined at FHD	8 Scour Countermeasures
Channel degradation	Potential?	3-7 feet	7.2 Long-term Degradation of the Channel Bed
Channel degradation	Allowed?	Yes	7.2 Long-term Degradation of the Channel Bed

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10 Final Design Considerations

The following items were beyond the scope of the PHD but should be addressed as part of the FHD:

1. Low-flow hydrology to be considered for WSE drop for step heights, see Section 3.0.
2. Detailed streambed material calculations for in-channel, see Section 4.3.1.
3. Detailed calculations for floodplain streambed material and stability to maintain the step features, see Section 4.3.1.
4. Additional design consideration should be given to adding sinuosity through the crossing to utilize the proposed structure dimension more fully.
5. Refinement of typical cross sections, see Section 4.1.2.
6. Detailed stability calculations for the LWM design, see Section 4.3.2.2.
7. Further modeling refinement will be required, see Section 5.4.
8. Flood risk assessment will be developed, see Section 6.1.
9. The LWM structures placed upstream of the crossing influencing lateral migration, see Section 7.1.
10. Further scour evaluation is required in conjunction with additional geotechnical data, see Section 7.2.

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Appendices

Appendix A: FEMA Floodplain Map

Appendix B: Hydraulic Field Report Form

Appendix C: Streambed Material Sizing Calculations

Appendix D: Stream Plan Sheets, Profile, Details

Appendix E: Manning's Calculations

Appendix F: Large Woody Material Calculations

Appendix G: Future Projections for Climate-Adapted Culvert Design

Appendix H: SRH-2D Model Results

Appendix I: SRH-2D Model Stability and Continuity

Appendix J: Reach Assessment

Appendix K: Scour Calculations

Appendix L: Floodplain Analysis (FHD ONLY)

Appendix M: Scour Countermeasure Calculations (FHD ONLY)

Appendix N: Hydrology Calculations

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Appendix A: FEMA Floodplain Map

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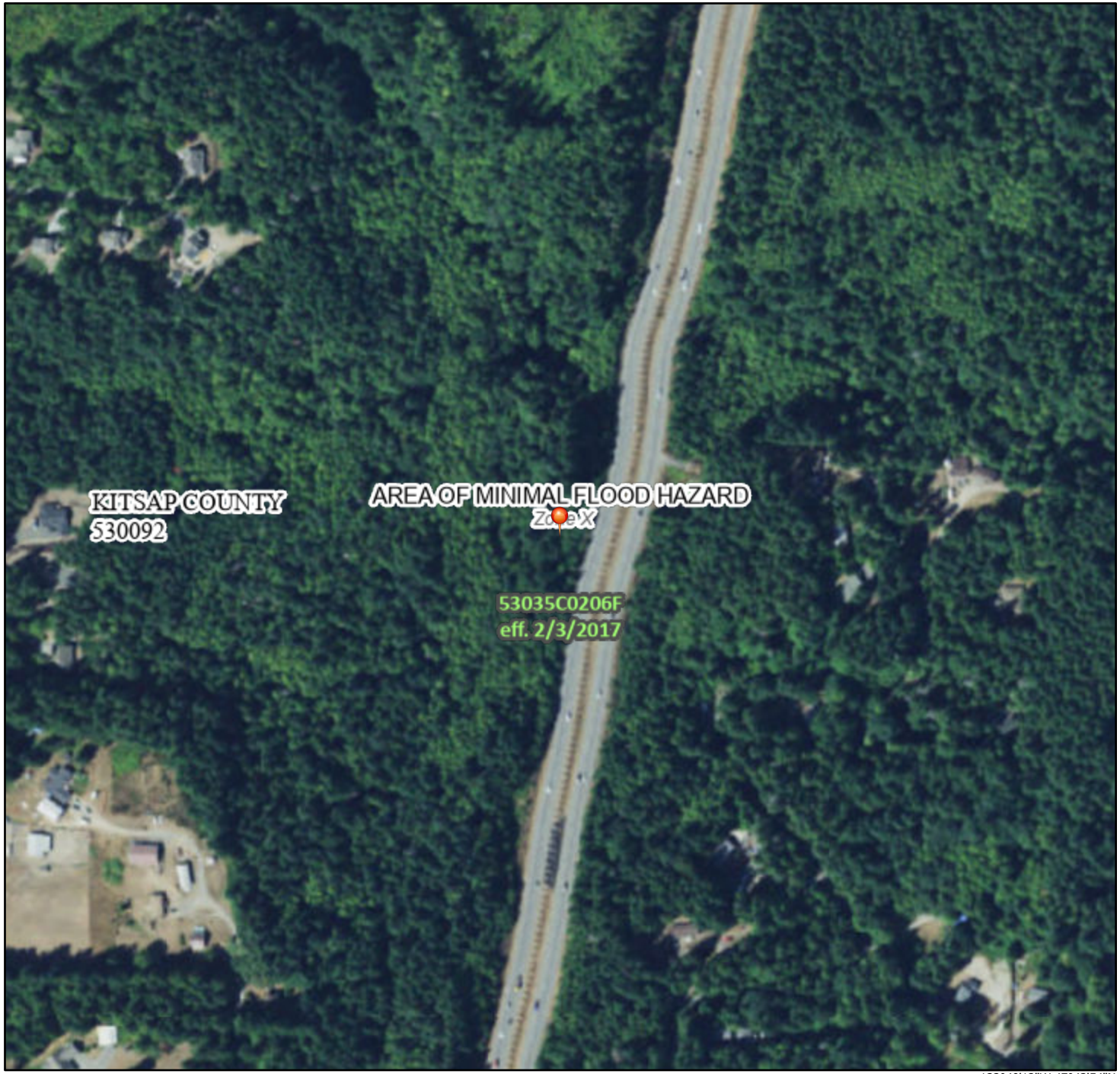
National Flood Hazard Layer FIRMette

FEMA

122°40'49"W 47°44'18"N



122°40'12"W 47°43'54"N

Feet

0 250 500 1,000 1,500 2,000

1:6,000

Basemap: USGS National Map: Orthoimagery: Data refreshed October, 2020

Legend

SEE FIS REPORT FOR DETAILED LEGEND AND INDEX MAP FOR FIRM PANEL LAYOUT

SPECIAL FLOOD HAZARD AREAS
- Without Base Flood Elevation (BFE) *Zone A, V, A99*
- With BFE or Depth *Zone AE, AO, AH, VE, AR*
- Regulatory Floodway

OTHER AREAS OF FLOOD HAZARD
- 0.2% Annual Chance Flood Hazard, Areas of 1% annual chance flood with average depth less than one foot or with drainage areas of less than one square mile *Zone X*
- Future Conditions 1% Annual Chance Flood Hazard *Zone X*
- Area with Reduced Flood Risk due to Levee. See Notes. *Zone X*
- Area with Flood Risk due to Levee *Zone D*

OTHER AREAS
- NO SCREEN Area of Minimal Flood Hazard *Zone X*
- Effective LOMRs
- Area of Undetermined Flood Hazard *Zone D*

GENERAL STRUCTURES
- Channel, Culvert, or Storm Sewer
- Levee, Dike, or Floodwall

OTHER FEATURES
- 20.2 Cross Sections with 1% Annual Chance
- 17.5 Water Surface Elevation
- Coastal Transect
- 513 Base Flood Elevation Line (BFE)
- Limit of Study
- Jurisdiction Boundary
- Coastal Transect Baseline
- Profile Baseline
- Hydrographic Feature

MAP PANELS
- Digital Data Available
- No Digital Data Available
- Unmapped

N

The pin displayed on the map is an approximate point selected by the user and does not represent an authoritative property location.

This map complies with FEMA's standards for the use of digital flood maps if it is not void as described below. The basemap shown complies with FEMA's basemap accuracy standards

The flood hazard information is derived directly from the authoritative NFHL web services provided by FEMA. This map was exported on 12/8/2021 at 1:32 PM and does not reflect changes or amendments subsequent to this date and time. The NFHL and effective information may change or become superseded by new data over time.

This map image is void if the one or more of the following map elements do not appear: basemap imagery, flood zone labels, legend, scale bar, map creation date, community identifiers, FIRM panel number, and FIRM effective date. Map images for unmapped and unmodernized areas cannot be used for regulatory purposes.

Appendix B: Hydraulic Field Report Form

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WSDOT Hydraulics Section	Hydraulics Field Report	Project Number: Y-12554
	Project Name: PHD South Fork Johnson Creek to Johnson Creek	Date: 12/1/2021
	Project Office: Jacobs Engineering Group Inc. Bellevue, WA	Time of Arrival: 8am
	Stream Name: SF Johnson Creek	Time of Departure: 12pm
WDFW ID Number: 991241	Tributary to: Johnson Creek	Weather: 60s and overcast
State Route/MP: SR 03 MP 50.85	Township/Range/Section/ ¼ Section: Township 26 North, Range 01 East, Section 21	Prepared By: Jacobs Engineering Group Inc.
County: Kitsap	Purpose of Site Visit: Site Visit #2	WRIA: WRIA 15

Meeting Location:
On Site

Attendance List:

Name	Organization	Role
Nich VanBuecken	Jacobs	Stream Restoration Engineer
Karen Williams	Jacobs	Geomorphologist
Sage Jensen	Jacobs	Fisheries Biologist
Morgan Ruark	Jacobs	Hydraulics Engineer
Mark Indrebo	Jacobs	Geomorphologist
Channing Syms	Jacobs	Stream Restoration Engineer

Bankfull Width:
Several bankfull width (BFW) measurements were taken and were between 5 and 10 feet. An initial suggested design BFW of 6-8 feet is based on the median field measurements taken in the reference reach. All BFW measurements are shown in the attached site sketch.

Reference Reach:
The upstream area of the stream was selected as the reference reach above the influence of the culvert in a riffle-run (or glide) reach. The area included undercut banks and a mix of legacy coniferous large woody material (LWM) of various stages of decay and newer deciduous LWM that has formed some pool sections. In this section, the bankfull widths were found to be 7 to 8 feet at the riffles and 6 to 7 feet at the runs. This area appears less disturbed since initial logging occurred on the old growth forests, aside from the road crossing placements. Stream habitat is suitable for spawning, rearing and migration of resident and anadromous fish species with more complex in-stream habitat upstream of the culvert. Suitable spawning gravels are present both upstream and downstream of the culvert.

Data Collection:
The SF Johnson Creek to Johnson Creek crossing was visited by Jacobs staff on December 1, 2021. Jacobs staff investigated approximately 300 feet upstream of the culvert inlet and 300 feet downstream of the culvert outlet. Staff measured several BFW measurements, pebble counts, and large woody material (LWM) in the system as noted throughout this field report. Additional observations on suitable habitat for anadromous and resident salmonids and trout were also made.

Observations:
The existing crossing consists of a 3-foot corrugated steel pipe running northwest to southeast at a skew to the elevated highway. The SR 03 road surface is approximately 60 to 80 vertical feet above the culvert. Upstream of the crossing, the channel exhibits two distinct reaches: 1) a lower gradient, wetland-like reach with indistinct banks, few streamside conifers, and relatively wide/shallow geometry; and 2) a higher gradient reach (further from the crossing) with well-defined banks, alternating riffle/run bedforms, some evidence of transport-limited conditions. The lower gradient reach is just upstream of the crossing and backwater conditions at the crossing appear to drive somewhat poorly defined channel geometry. Poorly defined meaning that the bankline and channel thalweg are not obvious, and the channel is typically wider and shallower. The barbed wire fence crossing of the channel is the location of the approximate transition to the higher gradient reach, outside of the influence of the crossing. This reach is

characterized by alternating riffle and run bedforms. A run is defined as a transitional bedform between a riffle and a pool, where flow is deeper than a riffle and steeper gradient than a pool. The channel has intermittent, obvious connection to the floodplain, but other subreaches are incised into the valley floor and are developing an inset floodplain in these subreaches. However, these subreaches show stable banks and no evidence of rapid, ongoing incision. The channel is typically wider in the riffles and narrower in runs. The channel exhibits local evidence of undercutting of banks to create side or pocket pools and immediate downstream deposition of locally derived sediment. These local areas of deposition create central or lateral bars that are not frequently mobilized (based on the imbrication of sediments and asymmetric macroinvetebrate colonization). Areas of the channel adjacent to these local depositional features are deepened, creating run/opposing bar, riffle/opposing bar bedforms. Evidence of transport-limited conditions includes persistent central and lateral bars. Sediment is moved through the thalweg but bar areas are persistent. LWM is typically channel spanning where interaction occurs through undercutting of conifer root wads and isolated smaller pieces (< 8 inches diameter breast height [DBH], < 8 feet length) than create limited steps across the channel. Channel bedforms appear more the result of differential bank and bed erosion and local deposition rather than the result of interaction with woody debris.

Deeper pools present upstream of the culvert, including cut banks and lateral pools, offer good complexity for spawning and rearing. LWM is present upstream of the culvert but most channel forming wood is legacy wood of more advanced stages of decay, no newer coniferous LWM is present. Very few in-stream LWM is present downstream of the culvert. Riparian cover is good both upstream and downstream of culvert with over 150 feet contiguous stand each bank of mid-late seral state coniferous forest composed primarily of Western red cedar and Western hemlock. Open understory, likely due to heavy shade in growing season, composed predominantly of natives. Area within 50 feet of culvert upstream and downstream of culvert is more open, higher percentage of deciduous species and non-natives in this road fill prism.

Downstream of the crossing, the channel morphology is driven by the confinement of the valley wall and interaction with frequent accumulations of LWM. The channel is largely riffle and step-pool. Local scour and deposition around LWM is common and the channel in incised into the valley surface. At this channel gradient, a significant floodplain is uncommon.

Pebble Counts:

The bed material is dominated by gravel, intermixed with cobbles, sand, and organic debris. Pebble counts were performed in both the upstream and downstream reaches, seen in the attached site sketch. Due to the small channel width, two modified pebble counts were performed in both the up- and downstream reach. The first upstream pebble count was between upstream BFW #4 and upstream BFW #5 in a riffle and yielded a D_{50} of 14 millimeters. The second upstream pebble count was between upstream BFW #4 and upstream BFW #5 in a glide and yielded a D_{50} of 18 millimeters. The first downstream pebble count was at downstream BFW #2 and yielded a D_{50} of 20 millimeters. The second downstream pebble count was at downstream BFW #1 and yielded a D_{50} of 32 millimeters.

Photos:

Site sketches with associated photos for the December 1st field visit are attached.

Samples:

Work within the wetted perimeter may only occur during the time periods authorized in the APP ID 21036 entitled "Allowable Freshwater Work Times May 2018". Work outside of the wetted perimeter may occur year-round. APPS website: https://www.govonlinesaas.com/WA/WDFW/Public/Client/WA_WDFW/Shared/Pages/Main/Login.aspx

Were any sample(s) collected from below the OHWM?	*No ☒ If no, then stop here.*			
	Yes ☐ If yes, then fill out the proceeding section for each sample.			
Sample #:	Work Start:	Work End:	Latitude:	Longitude:

Summary/description of location:

N/A

Description of work below the OHWL:

N/A

Description of problems encountered:

N/A

Concurrence Meeting	Date: 12/17/2021	Time of Arrival: 7:30am
Prepared By: Jacobs Engineering Group Inc.	Weather: 40s and overcast	Time of Departure: 12:00pm

Attendance List:

Name	Organization	Role
Nich VanBuecken	Jacobs	Stream Restoration Engineer
Michelle Kinsey	Jacobs	Stream Restoration Engineer
Heather Pittman	WSDOT	OR Design Manager
Alison O'Sullivan	Suquamish Tribe	Fish Biologist
Steven Seville	David Evans and Associates, Inc.	Stream Restoration Engineer
Cade Roler	WSDOT	OR Tribal Liaison
Amber Martens	WDFW	Fish Biologist
Dave Collins	WDFW	Fish Biologist
Damon Romero	WSDOT	Fish Biologist
Micco Emeson	David Evans and Associates, Inc.	Stream Restoration Engineer
Nam Siu	WDFW	Fish Biologist
Alexia Henderson	WDFW	Fish Biologist

Bankfull Width:

An upstream bankfull width (BFW) measurement was taken with all attendees and was determined be 7.5 feet with a bankfull depth of 1.3 feet. A downstream BFW measurement was taken with all attendees and was determined be 9 feet. Attendees agreed with a design BFW of 7-9 feet based on the field measurements taken in the new reference reach, discussed in further detail below. Additionally, valley width measurements were taken with all attendees as approximately 45 feet in the upstream reach and 30 feet in the downstream reach.

After the concurrence meeting, Jacobs staff remained and collected additional information in the newly selected reference reach including BFW measurements, pebble count, and large woody material (LWM) in the system as noted throughout this field report. Several bankfull width (BFW) measurements were taken and were between 7 and 9 feet, with an outlier of 18 feet above a LWM structure. All BFW measurements taken by Jacobs staff are shown in the attached site sketch. The bed material is dominated by gravel, intermixed with cobbles, sand, and organic debris. Pebble counts were performed in both the upstream and downstream reaches, seen in the attached site sketch. Due to the small channel width, a modified pebble count was performed in the new reference reach and yielded a D_{50} of 21 millimeters.

Reference Reach:

After viewing both the up- and downstream conditions, and discussing alternatives at a high level, the attendees agreed that a "replace in kind" approach with a 7 percent crossing with step-pools in the crossing with was the most appropriate to minimize impact to the surrounding habitat and avoid unnecessary grading up- and downstream of the crossing. Due to the chosen approach, a new reference reach approximately 220 feet downstream of the crossing and extending downstream approximately 70 feet, was determined as most appropriate in a reach as it had a slope of approximately 5-7 percent as determined in the field by a clinometer and confirmed by the survey. The area also included undercut banks and a mix of legacy coniferous large woody material (LWM) of various stages of decay and newer deciduous LWM that has formed some pool sections. Stream habitat is suitable for spawning, rearing, and migration of resident and anadromous fish species.

Observations:

The attendees agreed that the initial PHD approach will be a "replace in kind" approach with a 7 percent crossing that reflects the step-pool morphology in the reference reach to minimize impact to the surrounding habitat and avoid unnecessary grading up- and downstream of the crossing. Structure type will be evaluated later in the design process. Due to the length of the crossing, being held to 0.8' of water surface elevation change would require the steps to be

very close together. Attendees agreed that further discussion was necessary to see if deformable steps and/or steps greater than 0.8 feet in height would be acceptable.

WSDOT also noted that the design would need to take into account a way to mimic solid banks through the crossing. Attendees agreed that the grading extents should take into consideration the impact to the existing habitat; ideally, the proposed grading would not cut into the valley walls and would stay away from the downstream houses. Habitat within the crossing will need to include lateral resting pools and the Thalweg will transition from side to side rather than a straight alignment. Additionally, a wildlife connectivity memo is being prepared by WSDOT Headquarters wildlife connectivity staff

Photos:

Site sketches with associated photos for the December 17th field visit are attached.

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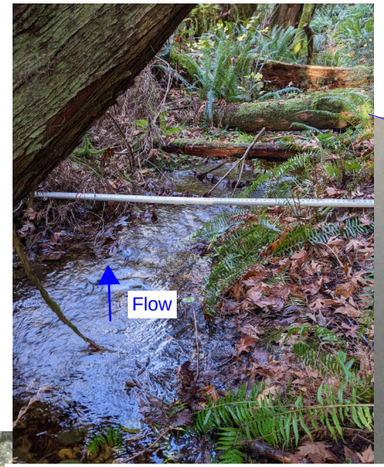
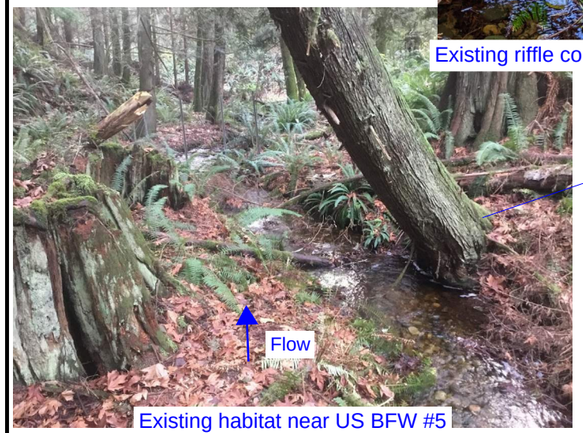
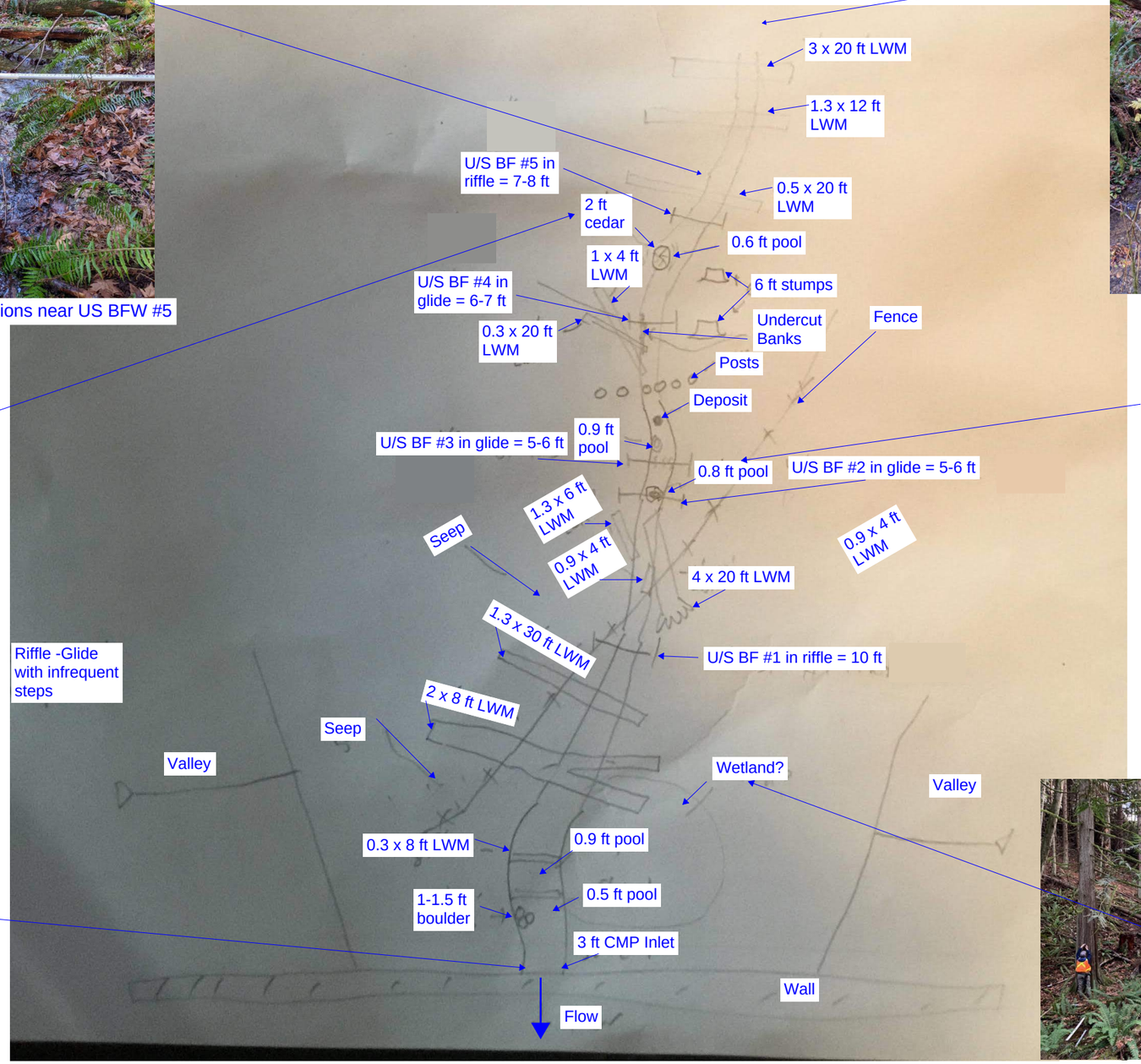


Existing riffle conditions near US BFW #5



Existing habitat near US BFW #5

Existing 36-inch crossing inlet



Scour under stump results in central bar deposition

Existing conditions near US BFW #2

Inlet and depositional wetland area

N

No.	DATE	DSN	CHK	APP	REVISION

DESIGNED BY: M. KINSEY
DRAWN BY: M.KINSEY
CHECKED BY:
APPROVED BY:

Jacobs

REVIEWED BY:
SUBMITTED BY:
LINE IS 1" AT FULL SCALE

SCALE: NTS
FILENAME: 5085_SFJOHNSONCRKTOJOHNSONCRK
CONTRACT No.: Y-12554
DATE: 11/29/2021
DESIGN PACKAGE:
PERMIT INFORMATION:

OLYMPIC REGION PHDS
Y-12554

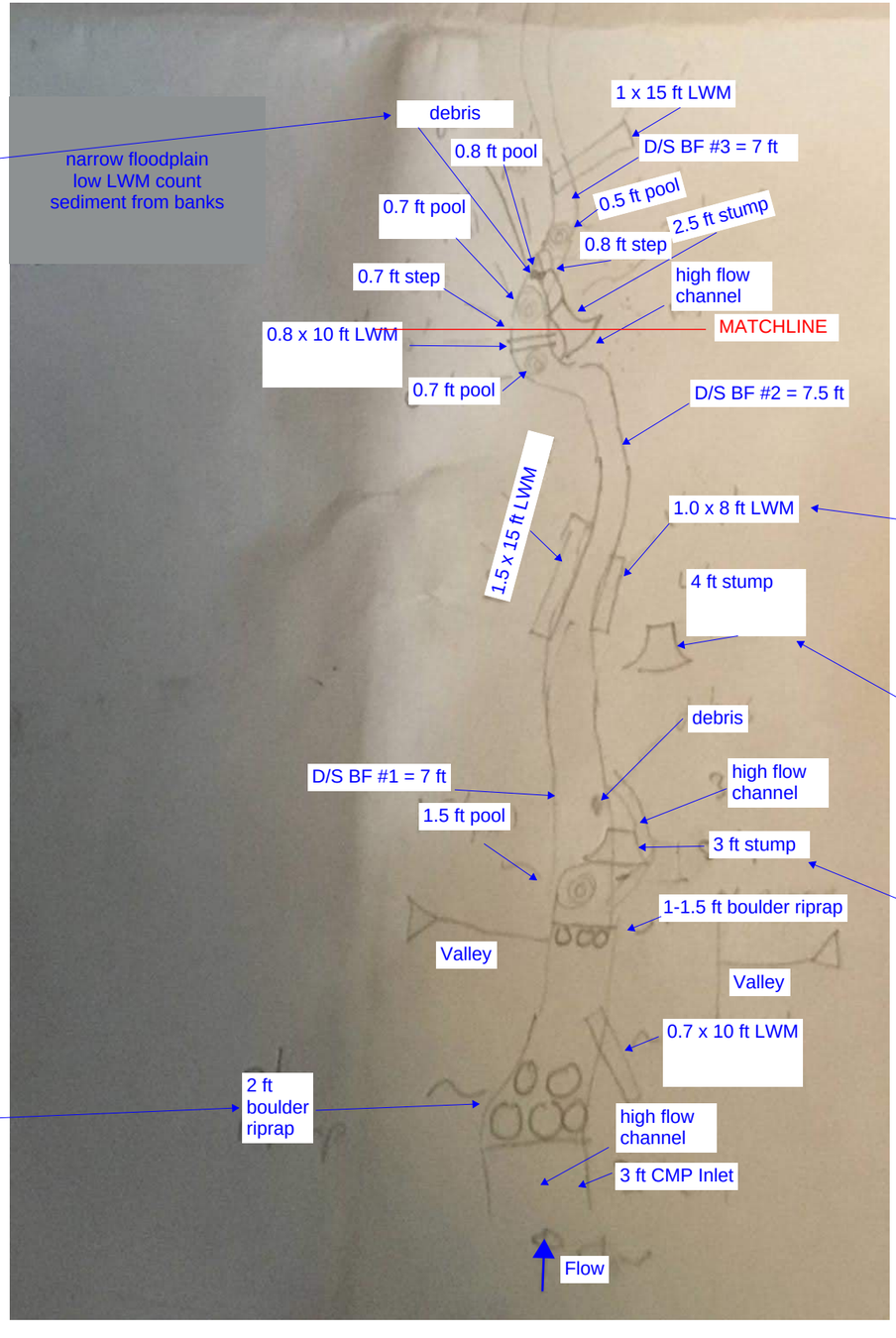
SF JOHNSON CREEK TO JOHNSON CREEK
UPSTREAM SITE SKETCH

DRAWING No.: PLAN 1
FACILITY ID:
SHEET No.: REV: 0

11/29/21 | 4:46 PM | KINSEYM2
P:\W3Y0500\600DISC\991241 SF JOHNSON CRICAD\5085_SFJOHNSONCRKTOJOHNSONCRK.DWG

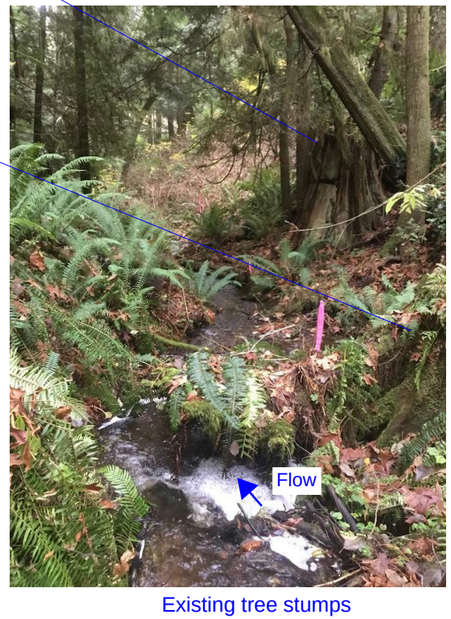
22x34 - Copy

Existing channel habitat at DS BFW #3



Existing LWM

Existing 36-inch crossing outlet



Existing tree stumps

11/29/21 | 4:46 PM | KINSEYM2
P:\W3Y05000600D\SC091241 SF JOHNSON CR\CAD\5085_SFJOHNSONCRKTOJOHNSONCRK.DWG

No.	DATE	DSN	CHK	APP	REVISION

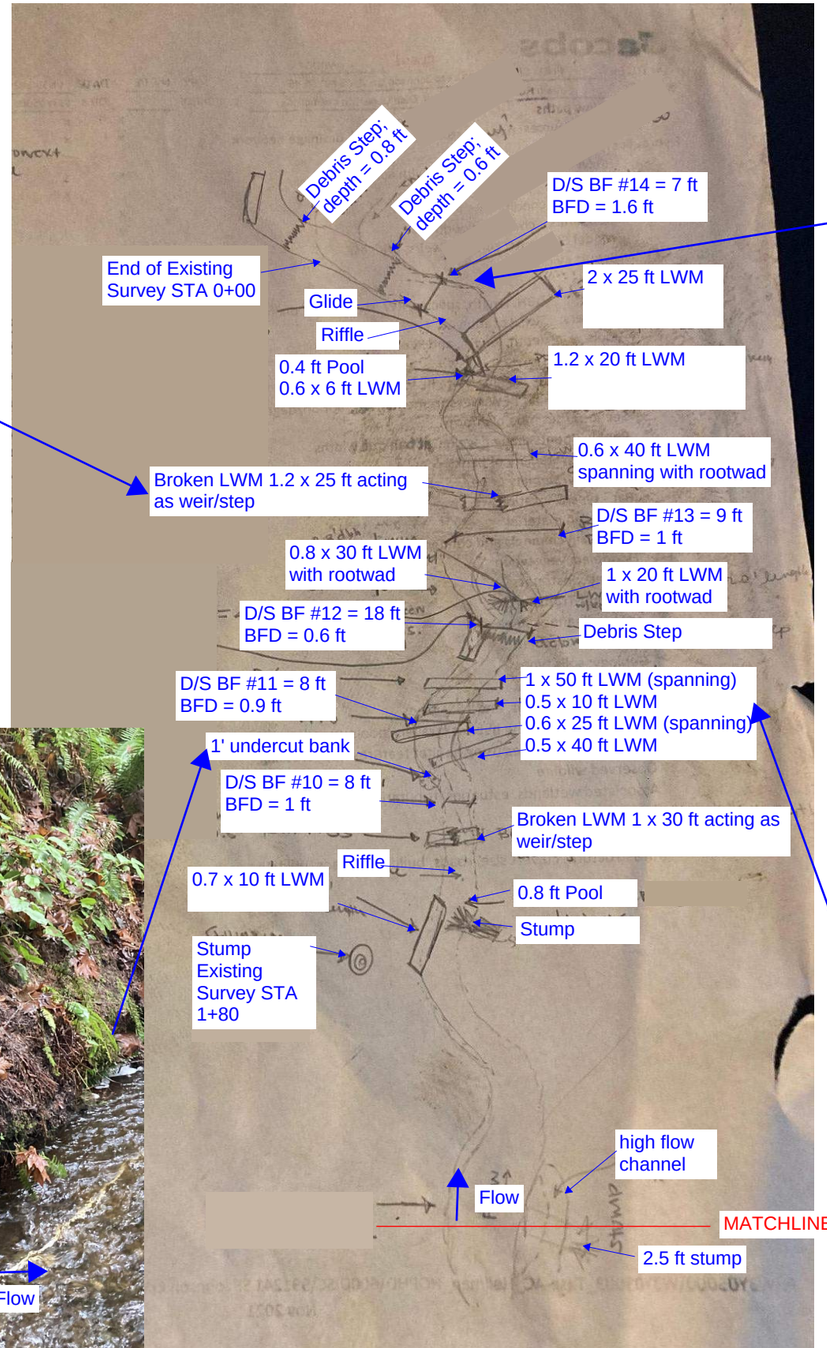
DESIGNED BY: M. KINSEY
DRAWN BY: M.KINSEY
CHECKED BY:
APPROVED BY:
REVIEWED BY:
SUBMITTED BY:
LINE IS 1" AT FULL SCALE
SCALE: NTS
FILENAME: 5085_SFJOHNSONCRKTOJOHNSONCRK
CONTRACT No.: Y-12554
DATE: 11/29/2021
DESIGN PACKAGE:
PERMIT INFORMATION:

OLYMPIC REGION PHDS
Y-12554

SF JOHNSON CREEK TO JOHNSON CREEK
DOWNSTREAM SITE SKETCH

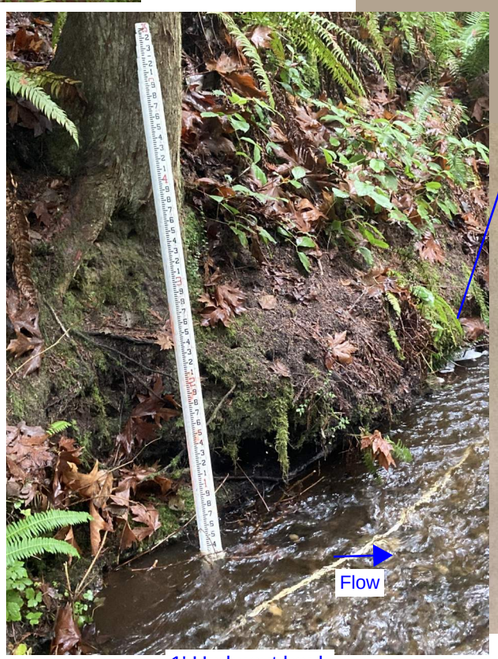
DRAWING No.: **PLAN 1**
FACILITY ID:
SHEET No.: 0
REV:

Broken log acting as step/weir.
Note BFW of 9 ft.



Typical Sediment in Reference Reach

LWM in Reference Reach



1' Undercut bank

N

No.	DATE	DSN	CHK	APP	REVISION

DESIGNED BY: M. KINSEY
DRAWN BY: M.KINSEY
CHECKED BY:
APPROVED BY:

Jacobs

REVIEWED BY:
SUBMITTED BY:
LINE IS 1" AT FULL SCALE

SCALE: NTS
FILENAME: 5085_SFJOHNSONCRKTOJOHNSONCRK
CONTRACT No.: Y-12554
DATE: 11/29/2021

DESIGN PACKAGE:
PERMIT INFORMATION:

OLYMPIC REGION PHDS
Y-12554

SF JOHNSON CREEK TO JOHNSON CREEK
DOWNSTREAM SITE SKETCH

DRAWING No.: PLAN 1
FACILITY ID:
SHEET No.: REV: 0

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11/29/21 | 4:46 PM | KINSEYM2
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Fish Passage Project Site Visit - Determining Project Complexity

PROJECT NAME:	SF Johnson Creek to Johnson Creek
WDFW SITE ID:	991241
STATE ROUTE/MILEPOST:	SR 03 MP 50.85
SITE VISIT DATE:	12/1/2021
ATTENDEES:	Nich VanBuecken, Karen Williams, Sage Jensen, Channing Syms
ANTICIPATED LEVEL OF PROJECT COMPLEXITY - Low/Medium/High (*additional considerations or red flags may trigger the need for new discussions*):	Medium due to long culvert and steep existing culvert vs existing stream gradient
IN WATER WORK WINDOW	

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The following elements of projects should be discussed before the production of a Preliminary Hydraulic Design by members of WSDOT and WDFW to identify the level of complexity for each site, and corresponding communication and review. While certain elements may be categorized as indicators of a low/medium/high complexity project, these are only suggestions, and newly acquired information may change the level of complexity during a project. The ultimate documentation category for a given site is up to both WSDOT and WDFW, considering both site characteristics and synergistic effects.

Discuss the following elements as they apply to the project. Rank each element as low, medium, or high in complexity. If there are items that need follow-up, mark those and provide a brief description in the column labeled, "Is follow up needed on this item?" The assigned level of complexity determines the appropriate agreed upon review from WDFW (see review parameters here (*final full doc goes here*)). Ultimately, WSDOT needs to acquire an HPA from WDFW for fish passage projects and the agreed upon communication and review of project elements will contribute to efficiencies in the permitting process.

Fish Passage Project Site Visit - Determining Project Complexity

Project Elements (anticipated)	Low Complexity	Medium Complexity	High Complexity	Is follow up needed on this item?
Stream grading			x	lots of road fill, 400 ft ex culvert, lots of grading downstream
Risk of degradation/aggradation	x			limited signs of large sediment load or downcutting
Channel realignment	x			valley location set
Expected stream movement	x			mature trees and high potential for LWM
Gradient		x		7% culvert, channel 3-4% up and downstream
Potential for backwater impacts	x			likely a wetland at ex inlet, otherwise no
Meeting requirements for freeboard	x			high roadway prism
Stream size, and Bankfull Width	x			BFW 6-8 ft
Slope ratio			x	ex culvert much steeper than channel
Sediment supply	x			see agg/deg
Meeting stream simulation	x			relatively straight crossing at this slope.
Channel confinement		x		wider floodplain upstream
Geotech or seismic considerations	x			didn't notice any in the field
Tidal influence	x			no
Alluvial fan	x			no
Fill depth above barrier			x	100 ft on downstream
Presence of other nearby barriers	x			closest is ~1,000 ft downstream
Presence of nearby infrastructure	x			none noticed in field or survey
Need for bank protection	x			not really as no hard meanders in stream
Floodplain utilization ratio		x		seems moderate upstream, confined downstream

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Fish Passage Project Site Visit - Determining Project Complexity

Other:				

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Appendix C: Streambed Material Sizing Calculations

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Attachment 1. SBM Sizing for Proposed Typical Channel using Bathhurst Equation

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Summary - Streambed Material Design Using Bathurst (1987)

Project:	**991241 SF Johnson PHD**
Completed By:	**M. Kinsey, EIT**
Reviewed By:	**N. Vanbuecken, PE**

Legend	
	computed values
	user input
	given

Determine D84 using Unit-Discharge Bed Design
Suitability of the method: for slopes > 4% or in under-fit channels
Sizing relationships from WCDG (2013), Eq-n.3.3, Pg48
Particle size at threshold of motion at critical unit discharge in coarse, high-gradient streams with heterogeneous beds

100 yr Width	W_f	**20**
Active Channel Top Width	W_b	**7**
100 yr Design Flow	Q_{100}	**85**
Roughened Ch.Slope (ft/ft)	S	**0.073**
Crit.unit discharge, cf/(ft-s)	q_c	**4.3**
Crit.unit discharge, cf/(ft-s)	q_c	**12.1**
Gravitational Constant ft/s^2	g	**32.2**
D_{84}, ft	D_{84}	**1.0**
D_{84}, in	D_{84}	**11.6**

$$D_{84} = 3.54 S^{0.747} (1.25 q_c)^{2/3} / g^{1/3}$$ **Equation 3.3**

$q_c = Q_{100}/W_f$ This assumes the full width

$q_c = Q_{100}/W_b$ *This assumes only the bankfull width, which over estimates proportional unit discharge. Consider Q within bankfull channel in further design steps.*

Calculate Gradation
Sizing relationships from WCDG (2013), Figure 3.8, Pg50

				Reference Reach Pebble Count	
D_{100}, in	D_{100}	**29.0**	>	**7.1**	D_{100}
D_{84}, in	D_{84}	**11.6**	>	**2.9**	D_{84}
D_{50}, in	D_{50}	**4.6**	>	**0.8**	D_{50}
D_{16}, in	D_{16}	**1.4**	>	**0.02**	D_{16}

Figure 3.8 represents a smooth curve between some basic relationships found in natural distributions, summarized in the following relationships as a function of D_{84}:

$D_{84}/D_{100} = 0.4$ **Equation 3.6**

$D_{84}/D_{50} = 2.5$ **Equation 3.7**

$D_{84}/D_{16} = 8.0$ **Equation 3.8**

In order to create a non-porous bed there must be a minimum of 5% to a maximum of 10% fines in the mix.

Summary
This gradation appears much more coarse than the native aggregate and will need to be refined during further design steps.

Attachment 2. SBM Sizing for Proposed Typical Cascade using Modified Critical Shear Stress Design Equation

DRAFT

Summary - Stream Simulation Bed Material Design

991241 SF Johnson SBM- Cascade

Project: 991241 SF Johnson PHD
By: M. Kinsey, EIT
Checked By: N. VanBuecken, PE

Streambed Mobility/Stability Analysis

Modified Shields Approach

References:
Stream Simulation: An Ecological Approach to Providing Passage for Aquatic Organizms at Road-Stream Crossings
Appendix E--Methods for Streambed Mobility/Stability Analysis

Limitations:
D_{84} must be between 0.40 in and 10 in
uniform bed material (Di < 20-30 times D50)
Slopes less than 5%
Sand/gravel streams with high relative submergence

Equation E.6 $\tau_{ci} = 102.6 \tau_{D50} D_i^{.83} D_{50}^{.17}$

γ_s	165	specific weight of sediment particle (lb/ft^3)
γ	62.4	specific weight of water (1b/ft^3)
τ_{D50}	0.052	dimensionless Shields parameter for D50, use table E.1 of USFS manual or assume 0.045 for poorly sorted channel bed

	Existing Gradation:				Design Gradation:				
	Location:	REF REACH PC #1			Location:	Design Gradadtion			
		D_{100}	D_{84}	D_{50}	D_{16}	D_{100}	D_{84}	D_{50}	D_{16}
	ft	0.59	0.24	0.07	0.00	1.00	0.83	0.31	0.06
	in	7.10	2.90	0.80	0.02	12.00	10.00	3.69	0.77
	mm	18.03	7.37	2.03	0.05	30.48	25.40	9.37	1.96

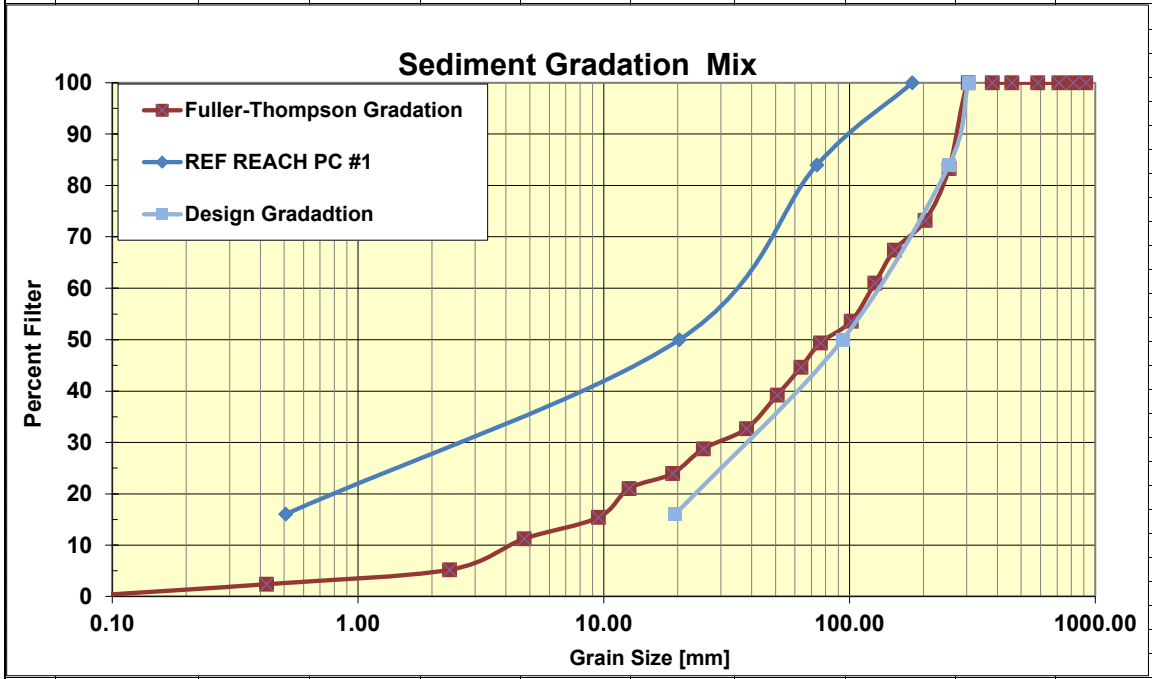
Determining Aggregate Proportions

Per WSDOT Standard Specifications 9-03.11

	Rock Size [in]	Rock Size [mm]	Streambed Sand	Streambed Sediment	Streambed Cobbles 4"	6"	8"	10"	12"	Streambed Boulders 12"-18"	18"-28"	28"-36"	D_{size}	Average Modeled Shear Stress (l	Flow	Low (5 cfs) Shear	Low (5 cfs) Grain	2-YR (21 cfs) Shear	2-YR (21 cfs) Grain	100-YR (85 cfs) Shear	100-YR (85 cfs) Grain
														τ_{ci}		0.93	0.73	1.62	1.3	2.54	2.14
Boulders	36.0	914										100	100.0	3.25		No Motion	No Motion	No Motion	No Motion	No Motion	No Motion
	32.0	813										50	100.0	3.13		No Motion	No Motion	No Motion	No Motion	No Motion	No Motion
	28.0	711									100		100.0	3.01		No Motion	No Motion	No Motion	No Motion	No Motion	No Motion
	23.0	584									50		100.0	2.84		No Motion	No Motion	No Motion	No Motion	No Motion	No Motion
	18.0	457								100			100.0	2.64		No Motion	No Motion	No Motion	No Motion	No Motion	No Motion
	15.0	381								50			100.0	2.50		No Motion	No Motion	No Motion	No Motion	Motion	No Motion
Cobbles	12.0	305							100				100.0	2.34		No Motion	No Motion	No Motion	No Motion	Motion	No Motion
	10.0	254						100	80				84.0	2.21		No Motion	No Motion	No Motion	No Motion	Motion	No Motion
	8.0	203					100	80	68				74.7	2.07		No Motion	No Motion	No Motion	No Motion	Motion	Motion
	6.0	152				100	80	68	57				65.3	1.90		No Motion	No Motion	No Motion	No Motion	Motion	Motion
	5.0	127				80	68	57	45				56.0	1.80		No Motion	No Motion	No Motion	No Motion	Motion	Motion
	4.0	102			100	71	57	45	39				51.4	1.68		No Motion	No Motion	No Motion	No Motion	Motion	Motion
Gravel	3.0	76.2			80	63	45	38	34				46.9	1.54		No Motion	No Motion	Motion	No Motion	Motion	Motion
	2.5	63.5		100	65	54	37	32	28				42.3	1.46		No Motion	No Motion	Motion	No Motion	Motion	Motion
	2.0	50.8		80	50	45	29	25	22				33.7	1.36		No Motion	No Motion	Motion	No Motion	Motion	Motion
	1.5	38.1		73	35	32	21	18	16				27.6	1.25		No Motion	No Motion	Motion	Motion	Motion	Motion
	1.0	25.4		65	20	18	13	12	11				21.6	1.11		No Motion	No Motion	Motion	Motion	Motion	Motion
	0.75	19.1		58	5	5	5	5	5				15.5	1.02		No Motion	No Motion	Motion	Motion	Motion	Motion
	0.50	12.7	100	50									10.0	0.90		Motion	No Motion	Motion	Motion	Motion	Motion
	0.38	9.5	90	43									8.5	0.83		Motion	No Motion	Motion	Motion	Motion	Motion
	No. 4 =	4.75	79	35									7.0								
	No. 8 =	2.36	67	26									5.1		Max Tau =	2.21					
Sand	No. 40 =	0.425	37	16									3.2		Flow	Low (5 cfs) Shear	Low (5 cfs) Grain	2-YR (21 cfs) Shear	2-YR (21 cfs) Grain	100-YR (85 cfs) Shear	100-YR (85 cfs) Grain
Silt	No. 200 =	0.0750	7	7									1.4		D84 FOS	2.4	3.0	1.4	1.7	0.9	1.0
	% per category		0	20	0	0	0	0	80	0	0	0	--> 100%								
	% Cobble & Sediment		0.0	20.0	0.0	0.0	0.0	0.0	80.0	0.0	0.0	0.0	100.0%								

%	mm	in	ft
15.5	19.1	0.8	0.063
16	19.6	0.8	0.064
21.6	25.4	1.0	0.083
46.86	76.2	3.0	0.250
50	93.7	3.7	0.307
51.43	101.6	4.0	0.333
84.00	254.0	10.0	0.833
84	254.0	10.0	0.833
84.00	254.0	10.0	0.833

Note: Additional streambed sand will be added to seal bed as directed by engineer, thus increasing fines amount



Fuller-Thompson Gradation			
Dmax =	304.8	12	
	D[mm]	D[in]	% passing
	914.400	36	100.00
	812.800	32	100.00
	711.200	28	100.00
	584.200	23	100.00
	457.200	18	100.00
	381.000	15	100.00
	304.800	12	100.00
	254.000	10	83.32
	203.200	8	73.20
	152.400	6	67.44
	127.000	5	61.00
	101.600	4	53.59
	76.200	3	49.37
	63.500	2.5	44.65
	50.800	2	39.23
	38.100	1.5	32.69
	25.400	1.00	28.72
	19.050	0.75	23.93
	12.700	0.50	21.02
	9.525	0.375	15.37
	4.750	0.187	11.22
	2.360	0.093	5.19
	0.425	0.017	2.38
	0.075	0.0030	0.00

Attachment 3. SBM Sizing for Proposed Typical Step using Modified Critical Shear Stress Design Equation

DRAFT

Summary - Stream Simulation Bed Material Design

991241 SF Johnson SBM- Step

Project: 991241 SF Johnson PHD
By: M. Kinsey, EIT
Checked By: N. VanBuecken, PE

Streambed Mobility/Stability Analysis

Modified Shields Approach

References:
Stream Simulation: An Ecological Approach to Providing Passage for Aquatic Organizms at Road-Stream Crossings
Appendix E--Methods for Streambed Mobility/Stability Analysis

Limitations:
D_{84} must be between 0.40 in and 10 in
uniform bed material (Di < 20-30 times D50)
Slopes less than 5%
Sand/gravel streams with high relative submergence

Equation E.6 $\tau_{ci} = 102.6\ \tau_{D50}\ D_i^{0.3}\ D_{50}^{0.7}$

γ_s	165	specific weight of sediment particle (lb/ft^3)
γ	62.4	specific weight of water (1b/ft^3)
τ_{D50}	0.054	dimensionless Shields parameter for D50, use table E.1 of USFS manual or assume 0.045 for poorly sorted channel bed

Design Gradation:
Location: REF REACH PC #1

	D_{100}	D_{84}	D_{50}	D_{16}
ft	0.59	0.24	0.07	0.00
in	7.10	2.90	0.80	0.02
mm	18.03	7.37	2.03	0.05

Design Gradation:
Location: Design Gradadtion

	D_{100}	D_{84}	D_{50}	D_{16}
ft	1.50	1.42	1.19	0.32
in	18.00	16.99	14.24	3.86
mm	45.72	43.15	36.16	9.80

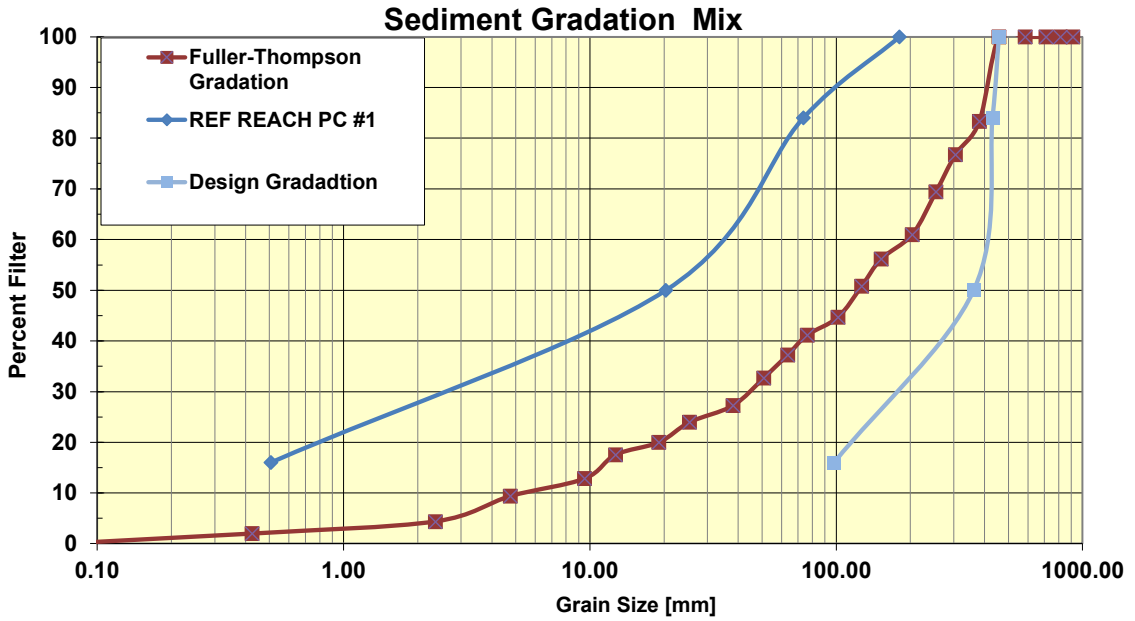
Determining Aggregate Proportions

Per WSDOT Standard Specifications 9-03.11

Rock Size [in]	Rock Size [mm]	Streambed Sand	Streambed Sediment	Streambed Cobbles 4"	6"	8"	10"	12"	Streambed Boulders 12"-18"	18"-28"	28"-36"	D_{size}	Average Modeled Shear Stress (τ_{ci})	Low (5 cfs) Shear	Low (5 cfs) Grain	2-YR (21 cfs) Shear	2-YR (21 cfs) Grain	100-YR (85 cfs) Shear	100-YR (85 cfs) Grain
													Flow	Low (5 cfs) Shear	Low (5 cfs) Grain	2-YR (21 cfs) Shear	2-YR (21 cfs) Grain	100-YR (85 cfs) Shear	100-YR (85 cfs) Grain
													Average Modeled Shear Stress (l	3.90	1.15	4.80	1.7	7.43	3.05
Boulders	36.0	914									100	100.0	8.68	No Motion	No Motion	No Motion	No Motion	No Motion	No Motion
	32.0	813									50	100.0	8.38	No Motion	No Motion	No Motion	No Motion	No Motion	No Motion
	28.0	711									100	100.0	8.05	No Motion	No Motion	No Motion	No Motion	No Motion	No Motion
	23.0	584									50	100.0	7.59	No Motion	No Motion	No Motion	No Motion	No Motion	No Motion
	18.0	457								100		100.0	7.05	No Motion	No Motion	No Motion	No Motion	Motion	No Motion
	15.0	381								50		52.5	6.68	No Motion	No Motion	No Motion	No Motion	Motion	No Motion
Cobbles	12.0	305							100			5.0	6.24	No Motion	No Motion	No Motion	No Motion	Motion	No Motion
	10.0	254						100	80			5.0	5.91	No Motion	No Motion	No Motion	No Motion	Motion	No Motion
	8.0	203					100	80	68			5.0	5.53	No Motion	No Motion	No Motion	No Motion	Motion	No Motion
	6.0	152				100	80	68	57			5.0	5.07	No Motion	No Motion	No Motion	No Motion	Motion	No Motion
	5.0	127				80	68	57	45			5.0	4.80	No Motion	No Motion	No Motion	No Motion	Motion	No Motion
	4.0	102			100	71	57	45	39			5.0	4.49	No Motion	No Motion	Motion	No Motion	Motion	No Motion
Gravel	3.0	76.2			80	63	45	38	34			5.0	4.12	No Motion	No Motion	Motion	No Motion	Motion	No Motion
	2.5	63.5		100	65	54	37	32	28			5.0	3.90	No Motion	No Motion	Motion	No Motion	Motion	No Motion
	2.0	50.8		80	50	45	29	25	22			5.0	3.65	Motion	No Motion	Motion	No Motion	Motion	No Motion
	1.5	38.1		73	35	32	21	18	16			5.0	3.35	Motion	No Motion	Motion	No Motion	Motion	No Motion
	1.0	25.4		65	20	18	13	12	11			5.0	2.96	Motion	No Motion	Motion	No Motion	Motion	Motion
	0.75	19.1		58	5	5	5	5	5			5.0	2.72	Motion	No Motion	Motion	No Motion	Motion	Motion
	0.50	12.7	100	50								5.0	2.41	Motion	No Motion	Motion	No Motion	Motion	Motion
	0.38	9.5	90	43								4.5	2.21	Motion	No Motion	Motion	No Motion	Motion	Motion
	No. 4 =	4.75	79	35								3.9							
	No. 8 =	2.36	67	26								3.4	Max Tau =	6.93					
Sand	No. 40 =	0.425	37	16								1.9	Flow	Low (5 cfs) Shear	Low (5 cfs) Grain	2-YR (21 cfs) Shear	2-YR (21 cfs) Grain	100-YR (85 cfs) Shear	100-YR (85 cfs) Grain
Silt	No. 200 =	0.0750	7	7								0.4	D84 FOS	1.8	6.0	1.4	4.2	0.9	2.3
	% per category		5	0	0	0	0	0	0	95	0	0	--> 100%						
	% Cobble & Sediment		5.0	0.0	0.0	0.0	0.0	0.0	0.0	95.0	0.0	0.0	100.0%						

%	mm	in	ft
5.0	12.7	0.5	0.042
16	98.0	3.9	0.321
52.5	381.0	15.0	1.250
5.00	12.7	0.5	0.042
50	361.6	14.2	1.186
52.50	381.0	15.0	1.250
52.50	381.0	15.0	1.250
84	431.5	17.0	1.416
100.00	457.2	18.0	1.500

Note: Additional streambed sand will be added to seal bed as directed by engineer, thus increasing fines amount



Fuller-Thompson Gradation			
Dmax =	457.2	18	
	D[mm]	D[in]	% passing
	914.400	36	100.00
	812.800	32	100.00
	711.200	28	100.00
	584.200	23	100.00
	457.200	18	100.00
	381.000	15	83.32
	304.800	12	76.76
	254.000	10	69.43
	203.200	8	61.00
	152.400	6	56.19
	127.000	5	50.82
	101.600	4	44.65
	76.200	3	41.13
	63.500	2.5	37.20
	50.800	2	32.69
	38.100	1.5	27.23
	25.400	1.00	23.93
	19.050	0.75	19.94
	12.700	0.50	17.52
	9.525	0.375	12.81
	4.750	0.187	9.35
	2.360	0.093	4.32
	0.425	0.017	1.98
	0.075	0.0030	0.00

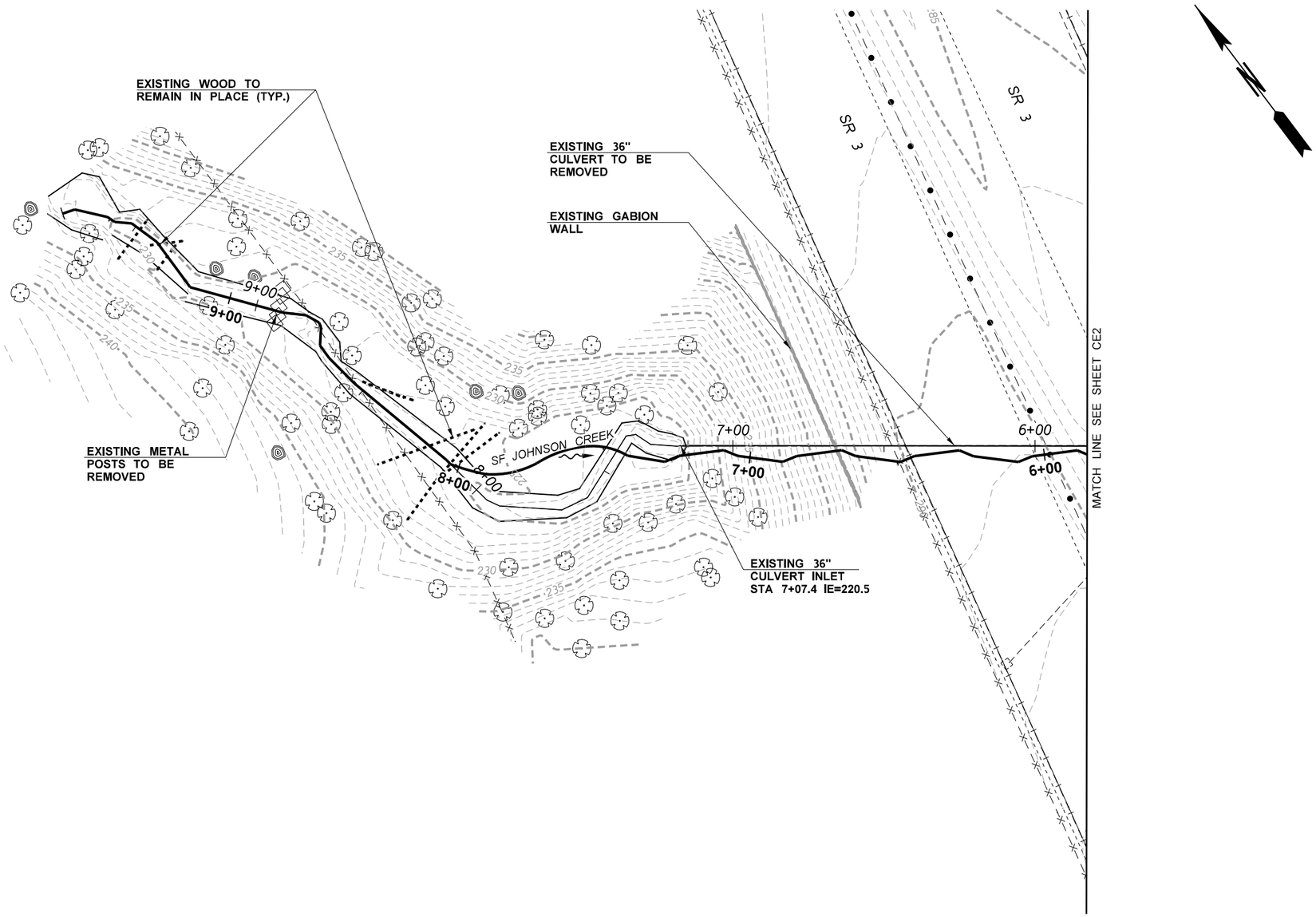
Appendix D: Stream Plan Sheets, Profile, Details

DRAFT

T.24N. R.1E. W.M.

LEGEND

- EXISTING STREAM ALIGNMENT — 5+00
- PROPOSED STREAM ALIGNMENT — 5+00
- EXISTING INDEX CONTOUR — 250
- EXISTING INTERMEDIATE CONTOUR
- EXISTING STREAM BANK TOP
- EXISTING EDGE OF PAVEMENT
- EXISTING FENCE
- EXISTING CABLE BARRIER
- EXISTING LARGE WOODY MATERIAL
- EXISTING GUARDRAIL
- EXISTING CULVERT
- EXISTING METAL POSTS
- EXISTING TREE
- EXISTING TREE STUMP



NOTES:

1. HORIZONTAL DATUM: PROJECT DATUM
2. VERTICAL DATUM: NAVD88
3. FIELD SURVEY PERFORMED BY WSDOT IN SEPTEMBER 2021.

0 20 40
SCALE IN FEET

PRELIMINARY - NOT FOR CONSTRUCTION

FILE NAME	c:\pw_wsdot\d0462792\XL_xxxx_PS_CE_001.dgn				REGION NO. 10	STATE WASH	FED.AID PROJ.NO.
TIME	2:16:55 PM						
DATE	6/23/2022				JOB NUMBER Y-12554		
PLOTTED BY	Mike Keilbart						
DESIGNED BY	M. KINSEY				CONTRACT NO.	LOCATION NO. XL_____	
ENTERED BY	M. KEILBART						
CHECKED BY	N. VANBUECKEN						
PROJ. ENGR.	J. HEILMAN						
REGIONAL ADM.		REVISION	DATE	BY			

P.E. STAMP BOX — DATE

P.E. STAMP BOX — DATE

Washington State Department of Transportation

SR 3 MP 50.85
991241 SF JOHNSON CREEK TO JOHNSON CREEK FISH BARRIER REMOVAL

EXISTING STREAM PLAN

PLAN REF NO CE1

SHEET 1 OF 7 SHEETS

pw:\\HQOLYMAPPPW03P.WSDOT.LOC:WSDOT\Documents_HQ\Fish Passage\ORproj\000\Y12554\Task Order AC\700PROJTEC\2_PHD_Working\SR003_MP50-85_SFJohnsonCktoJohnsonCk_991241_CAD_Sheets\XL_xxxx_PS_CE_001.dgn

T.24N. R.1E. W.M.

LEGEND

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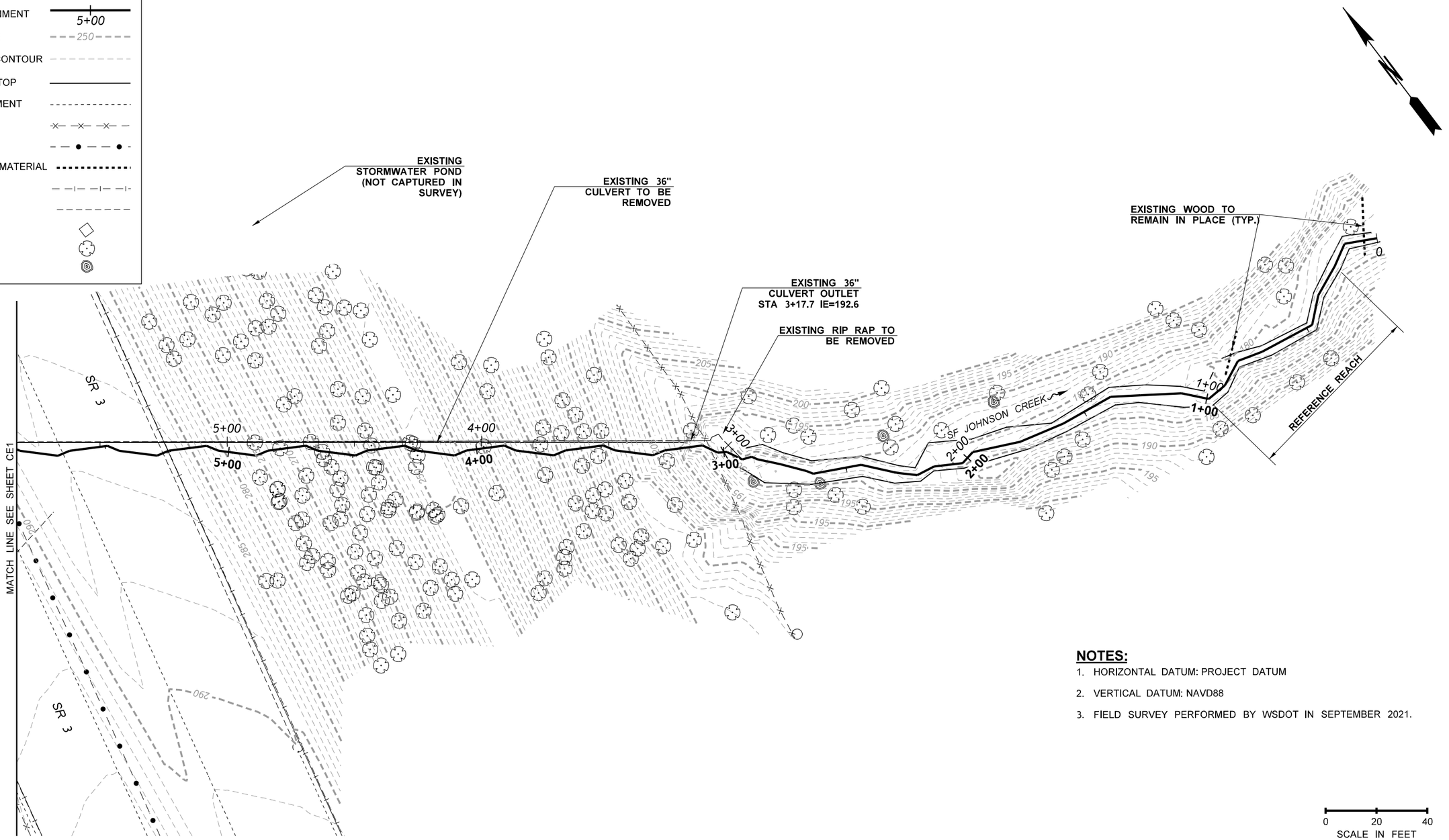
- PROPOSED STREAM ALIGNMENT — 5+00
- EXISTING INDEX CONTOUR — 250
- EXISTING INTERMEDIATE CONTOUR
- EXISTING STREAM BANK TOP
- EXISTING EDGE OF PAVEMENT
- EXISTING FENCE
- EXISTING CABLE BARRIER
- EXISTING LARGE WOODY MATERIAL
- EXISTING GUARDRAIL
- EXISTING CULVERT
- EXISTING METAL POSTS
- EXISTING TREE
- EXISTING TREE STUMP



NOTES:

1. HORIZONTAL DATUM: PROJECT DATUM
2. VERTICAL DATUM: NAVD88
3. FIELD SURVEY PERFORMED BY WSDOT IN SEPTEMBER 2021.

0 20 40
SCALE IN FEET

PRELIMINARY - NOT FOR CONSTRUCTION

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ENTERED BY	M. KEILBART						
CHECKED BY	N. VANBUECKEN				CONTRACT NO.	LOCATION NO. XL_____	
PROJ. ENGR.	J. HEILMAN						
REGIONAL ADM.		REVISION	DATE	BY			

P.E. STAMP BOX — DATE

P.E. STAMP BOX — DATE

Washington State Department of Transportation

SR 3 MP 50.85
991241 SF JOHNSON CREEK TO JOHNSON CREEK FISH BARRIER REMOVAL

EXISTING STREAM PLAN

PLAN REF NO CE2

SHEET 2 OF 7 SHEETS

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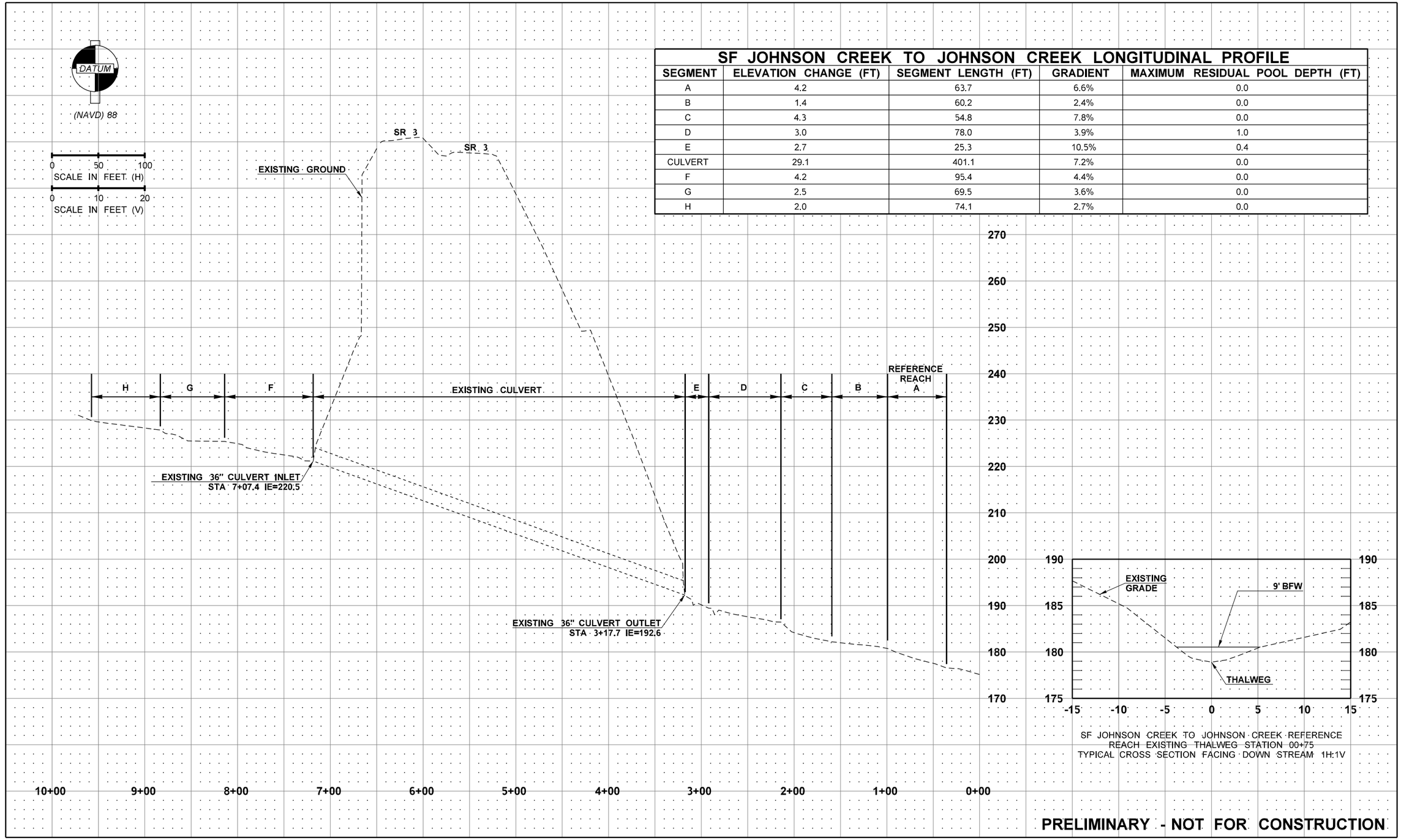
SF JOHNSON CREEK TO JOHNSON CREEK LONGITUDINAL PROFILE

SEGMENT	ELEVATION CHANGE (FT)	SEGMENT LENGTH (FT)	GRADIENT	MAXIMUM RESIDUAL POOL DEPTH (FT)
A	4.2	63.7	6.6%	0.0
B	1.4	60.2	2.4%	0.0
C	4.3	54.8	7.8%	0.0
D	3.0	78.0	3.9%	1.0
E	2.7	25.3	10.5%	0.4
CULVERT	29.1	401.1	7.2%	0.0
F	4.2	95.4	4.4%	0.0
G	2.5	69.5	3.6%	0.0
H	2.0	74.1	2.7%	0.0



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DATE	6/23/2022				JOB NUMBER		
PLOTTED BY	Mike Keilbart				Y-12554		
DESIGNED BY	M. KINSEY				CONTRACT NO.		LOCATION NO.
ENTERED BY	M. KEILBART						XL_____
CHECKED BY	N. VANBUECKEN						
PROJ. ENGR.	J. HEILMAN						
REGIONAL ADM.		REVISION	DATE	BY			

P.E. STAMP BOX DATE

P.E. STAMP BOX DATE

Washington State Department of Transportation

SR 3 MP 50.85
991241 SF JOHNSON CREEK TO JOHNSON CREEK FISH BARRIER REMOVAL

EXISTING STREAM PROFILE

PLAN REF. NO. CP1

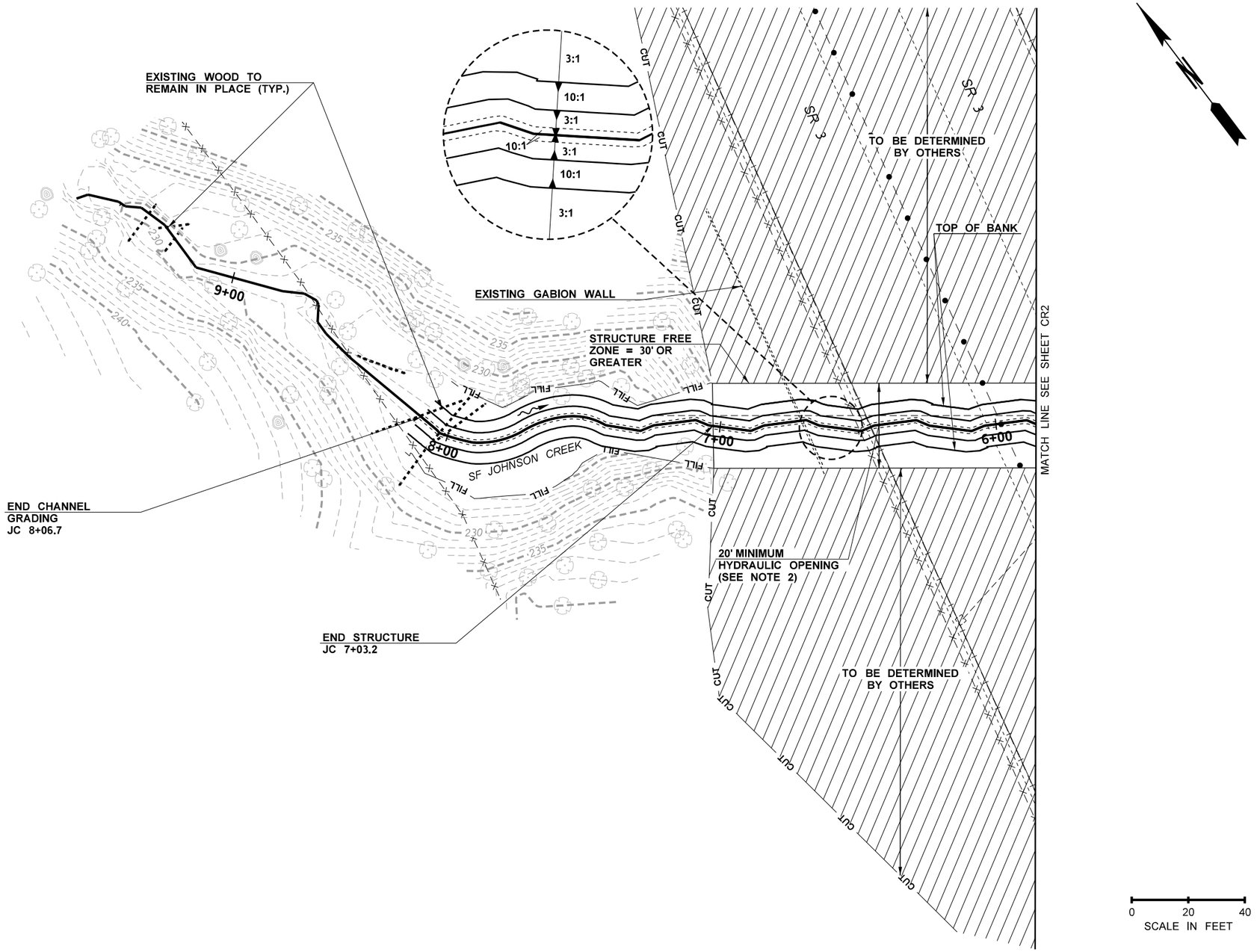
SHEET 3 OF 7 SHEETS

pw:\\HQOLYMAPPPW03P.WSDOT.LOC:WSDOT\Documents_HQ\Fish Passage\ORproj\000\Y12554\Task Order AC\700PROJTEC\2_PHD_Working\SR003_MP50-85_SFJohnsonCktoJohnsonCk_991241_CAD_Sheets\XL_xxxx_PS_CR_001.dgn

LEGEND

- PROPOSED STREAM ALIGNMENT — 5+00
- EXISTING INDEX CONTOUR — 250
- EXISTING INTERMEDIATE CONTOUR
- EXISTING STREAM BANK TOP
- EXISTING EDGE OF PAVEMENT
- EXISTING CULVERT
- EXISTING GUARDRAIL
- EXISTING FENCE
- EXISTING CABLE BARRIER
- EXISTING LARGE WOODY MATERIAL
- EXISTING TREE
- EXISTING TREE STUMP
- PROPOSED STUCTURE
- PROPOSED CUT LINE — CUT
- PROPOSED FILL LINE — FILL
- PROPOSED SLOPE LINE
- CUT TO BE DETERMINED BY OTHERS — CUT / CUT

T.24N. R.1E. W.M.



NOTES:

1. PROPOSED STRUCTURE SHOWN FOR ILLUSTRATION PURPOSES ONLY. STRUCTURE TYPE, SIZE, AND LOCATION TO BE DETERMINED AT LATER PHASE OF DESIGN.
2. PROPOSED STRUCTURE SHALL NOT ENCROACH INTO HYDRAULIC OPENING SHOWN IN PLAN.
3. GRADING LIMITS SHOWN ARE FOR ILLUSTRATION PURPOSES ONLY. FINAL LIMITS TO BE DETERMINED BASED ON FINAL STRUCTURE TYPE, SIZE, AND LOCATION.
4. FOR PROPOSED HABITAT FEATURES, SEE PHD FIGURES.
5. EXACT STRUCTURE TYPE, SIZE, LOCATION, AND WALLS TO BE DETERMINED.

PRELIMINARY - NOT FOR CONSTRUCTION

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DESIGNED BY	M. KINSEY						
ENTERED BY	M. KEILBART						
CHECKED BY	N. VANBUECKEN						
PROJ. ENGR.	J. HEILMAN						
REGIONAL ADM.		REVISION	DATE	BY			

REGION NO. 10 | STATE WASH | JOB NUMBER Y-12554 | CONTRACT NO. | FED.AID PROJ.NO. | LOCATION NO. XL_____

P.E. STAMP BOX — DATE

P.E. STAMP BOX — DATE

Washington State Department of Transportation

SR 3 MP 50.85
991241 SF JOHNSON CREEK TO JOHNSON CREEK
FISH BARRIER REMOVAL

STREAM PLAN

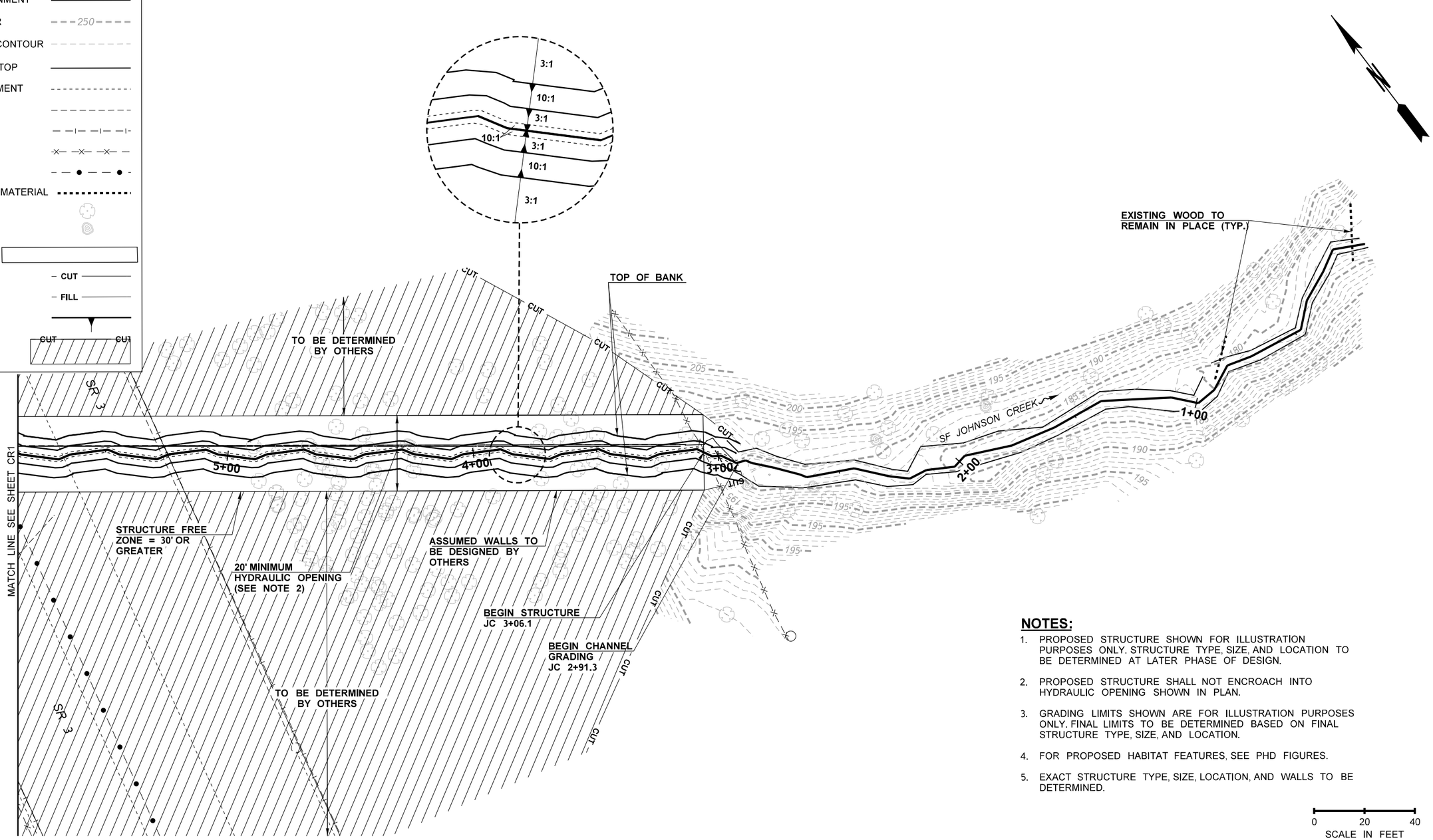
PLAN REF NO CR1

SHEET 4 OF 7 SHEETS

T.24N. R.1E. W.M.

LEGEND

- PROPOSED STREAM ALIGNMENT — 5+00
- EXISTING INDEX CONTOUR — 250
- EXISTING INTERMEDIATE CONTOUR
- EXISTING STREAM BANK TOP
- EXISTING EDGE OF PAVEMENT
- EXISTING CULVERT
- EXISTING GUARDRAIL
- EXISTING FENCE
- EXISTING CABLE BARRIER
- EXISTING LARGE WOODY MATERIAL
- EXISTING TREE
- EXISTING TREE STUMP
- PROPOSED STUCTURE
- PROPOSED CUT LINE — CUT
- PROPOSED FILL LINE — FILL
- PROPOSED SLOPE LINE
- CUT TO BE DETERMINED BY OTHERS — CUT / CUT



NOTES:

1. PROPOSED STRUCTURE SHOWN FOR ILLUSTRATION PURPOSES ONLY. STRUCTURE TYPE, SIZE, AND LOCATION TO BE DETERMINED AT LATER PHASE OF DESIGN.
2. PROPOSED STRUCTURE SHALL NOT ENCROACH INTO HYDRAULIC OPENING SHOWN IN PLAN.
3. GRADING LIMITS SHOWN ARE FOR ILLUSTRATION PURPOSES ONLY. FINAL LIMITS TO BE DETERMINED BASED ON FINAL STRUCTURE TYPE, SIZE, AND LOCATION.
4. FOR PROPOSED HABITAT FEATURES, SEE PHD FIGURES.
5. EXACT STRUCTURE TYPE, SIZE, LOCATION, AND WALLS TO BE DETERMINED.

0 20 40
SCALE IN FEET

PRELIMINARY - NOT FOR CONSTRUCTION

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PLOTTED BY	Mike Keilbart						
DESIGNED BY	M. KINSEY						
ENTERED BY	M. KEILBART						
CHECKED BY	N. VANBUECKEN						
PROJ. ENGR.	J. HEILMAN						
REGIONAL ADM.		REVISION	DATE	BY			

P.E. STAMP BOX — DATE

P.E. STAMP BOX — DATE

Washington State Department of Transportation

SR 3 MP 50.85
991241 SF JOHNSON CREEK TO JOHNSON CREEK
FISH BARRIER REMOVAL

STREAM PLAN

PLAN REF NO CR2

SHEET 5 OF 7 SHEETS

pw:\\HQOLY\MAPPPW03P.WSDOT.LOC:WSDOT\Documents_HQ\Fish Passage\ORproj\000\Y12554\Task Order AC\700PROJTEC\2_PHD_Working\SR003_MP50-85_SFJohnsonCktoJohnsonCk_9912411_CAD_Sheets\XL_xxxx_PS_CR_002.dgn

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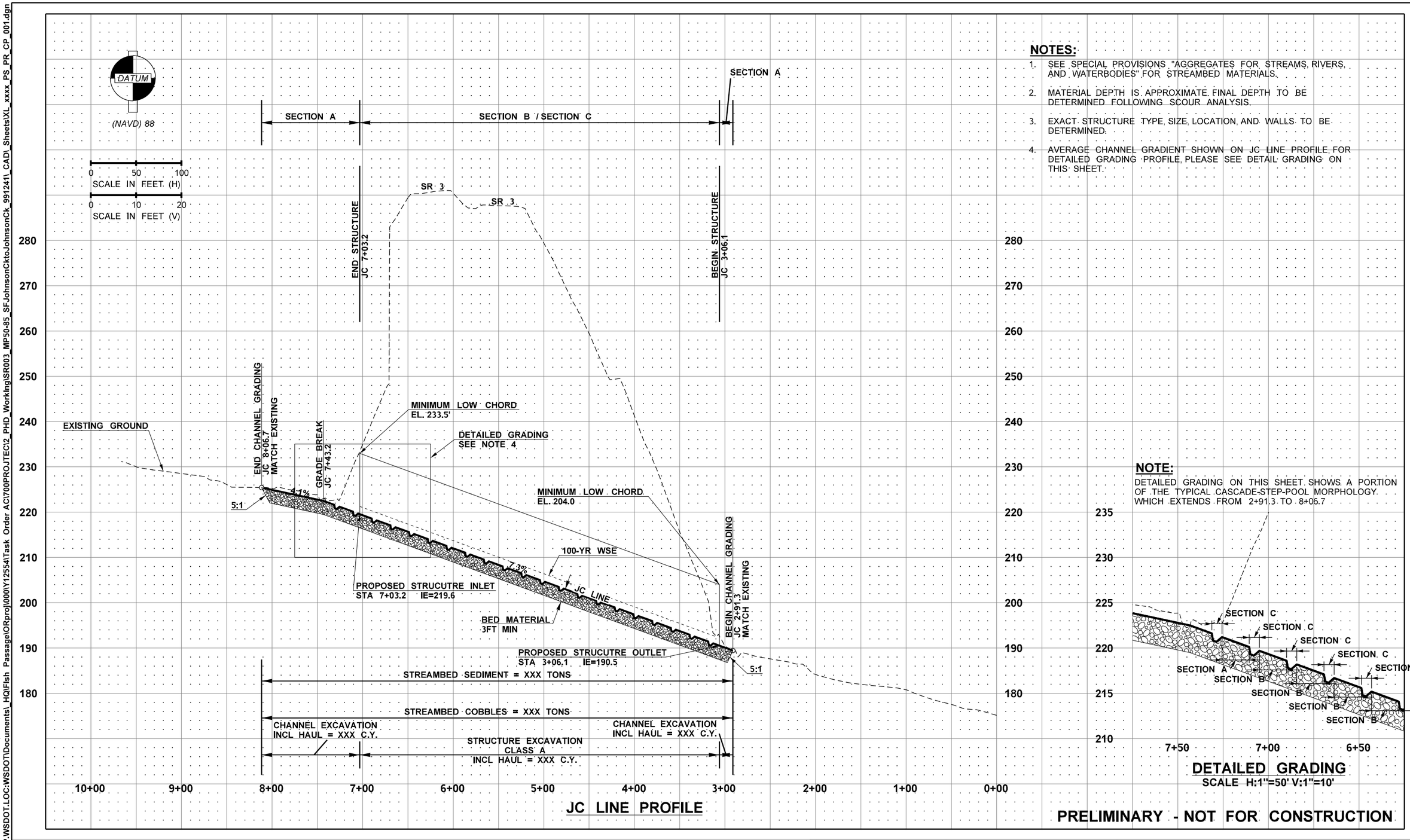

NOTES:

1. SEE SPECIAL PROVISIONS "AGGREGATES FOR STREAMS, RIVERS, AND WATERBODIES" FOR STREAMBED MATERIALS.
2. MATERIAL DEPTH IS APPROXIMATE. FINAL DEPTH TO BE DETERMINED FOLLOWING SCOUR ANALYSIS.
3. EXACT STRUCTURE TYPE, SIZE, LOCATION, AND WALLS TO BE DETERMINED.
4. AVERAGE CHANNEL GRADIENT SHOWN ON JC LINE PROFILE. FOR DETAILED GRADING PROFILE, PLEASE SEE DETAIL GRADING ON THIS SHEET.

NOTE:
DETAILED GRADING ON THIS SHEET SHOWS A PORTION OF THE TYPICAL CASCADE-STEP-POOL MORPHOLOGY. WHICH EXTENDS FROM 2+91.3 TO 8+06.7

DETAILED GRADING
SCALE H:1"=50' V:1"=10'

PRELIMINARY - NOT FOR CONSTRUCTION

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DESIGNED BY	M. KINSEY
ENTERED BY	M. KEILBART
CHECKED BY	N. VANBUECKEN
PROJ. ENGR.	J. HEILMAN
REGIONAL ADM.	

REVISION	DATE	BY

REGION NO. 10 | STATE WASH
JOB NUMBER Y-12554
CONTRACT NO.
FED.AID PROJ.NO.
LOCATION NO. XL_____

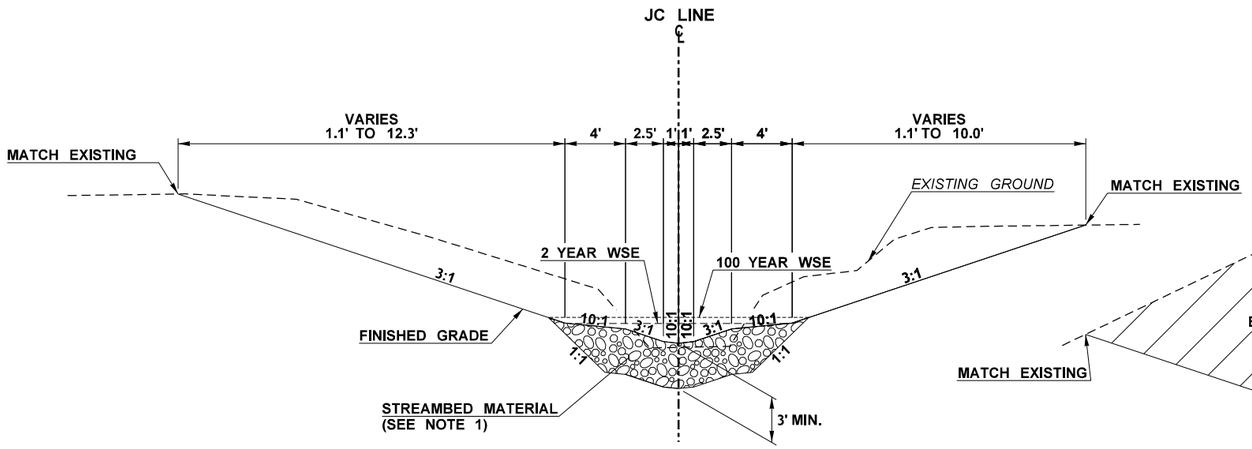
P.E. STAMP BOX DATE
P.E. STAMP BOX DATE

Washington State Department of Transportation

SR 3 MP 50.85
991241 SF JOHNSON CREEK TO JOHNSON CREEK
FISH BARRIER REMOVAL

STREAM PROFILE

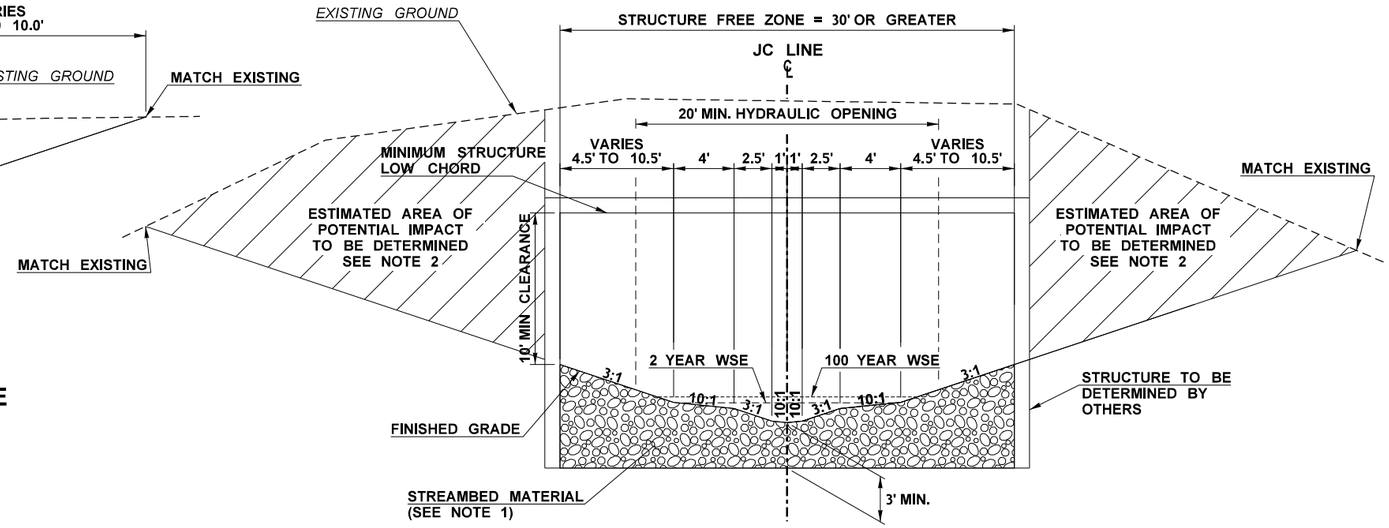
PLAN REF. NO. CP2
SHEET 6 OF 7 SHEETS



TYPICAL CASCADE OUTSIDE STRUCTURE
SECTION A

STATION
JC 2+91.3 TO 3+06.1
JC 7+03.2 TO 8+06.7

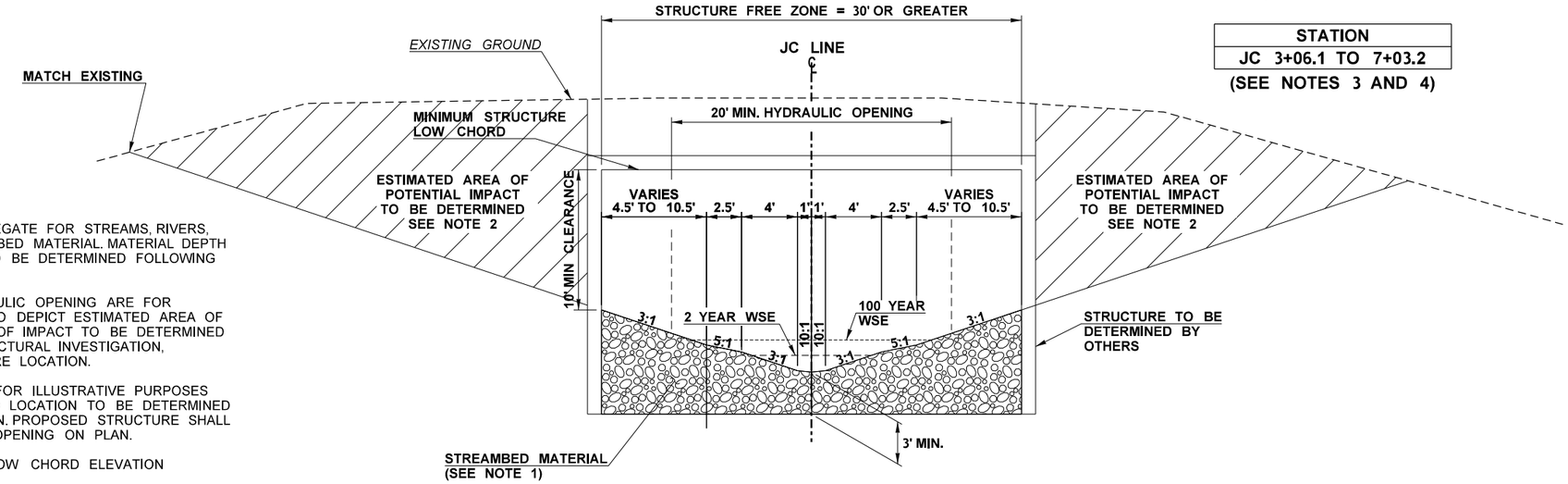
(SEE NOTES 3 AND 4)



TYPICAL CASCADE INSIDE STRUCTURE
SECTION B

STATION
JC 3+06.1 TO 7+03.2

(SEE NOTES 3 AND 4)



TYPICAL POOL INSIDE STRUCTURE
SECTION C

STATION
JC 3+06.1 TO 7+03.2

NOTES:

1. SEE SPECIAL PROVISIONS "AGGREGATE FOR STREAMS, RIVERS, AND WATERBODIES" FOR STREAMBED MATERIAL. MATERIAL DEPTH IS APPROXIMATE. FINAL DEPTH TO BE DETERMINED FOLLOWING SCOUR ANALYSIS.
2. SLOPES SHOWN OUTSIDE HYDRAULIC OPENING ARE FOR ILLUSTRATIVE PURPOSES ONLY TO DEPICT ESTIMATED AREA OF POTENTIAL IMPACT. FINAL AREAS OF IMPACT TO BE DETERMINED PENDING GEOLOGICAL AND STRUCTURAL INVESTIGATION, STRUCTURE TYPE, AND STRUCTURE LOCATION.
3. PROPOSED STRUCTURE SHOWN FOR ILLUSTRATIVE PURPOSES ONLY. STRUCTURE TYPE, SIZE, AND LOCATION TO BE DETERMINED DURING LATER PHASE OF DESIGN. PROPOSED STRUCTURE SHALL NOT ENCROACH INTO MINIMUM OPENING ON PLAN.
4. SEE SHEET CP2 FOR MINIMUM LOW CHORD ELEVATION THROUGHOUT STRUCTURE.
5. FROM 2+81.3 TO 2+91.3, EVENLY TAPER SECTION A TO MATCH EXISTING
6. FROM 8+06.7 TO 8+16.7, EVENLY TAPER SECTION A TO MATCH EXISTING
7. MATERIAL DEPTH IS APPROXIMATE. FINAL DEPTH TO BE DETERMINED FOLLOWING SCOUR ANALYSIS

0 5 10
SCALE IN FEET

PRELIMINARY - NOT FOR CONSTRUCTION

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DESIGNED BY	M. KINSEY				CONTRACT NO.		LOCATION NO.
ENTERED BY	M. KEILBART						XL_____
CHECKED BY	N. VANBUECKEN						
PROJ. ENGR.	J. HEILMAN						
REGIONAL ADM.		REVISION	DATE	BY			

P.E. STAMP BOX — DATE

P.E. STAMP BOX — DATE

Washington State Department of Transportation

SR 3 MP 50.85
991241 SF JOHNSON CREEK TO JOHNSON CREEK FISH BARRIER REMOVAL

STREAM DETAILS

PLAN REF NO CD1

SHEET 7 OF 7 SHEETS

pw:\\HQOLYMAPPPW03P.WSDOT.LOC:\WSDOT\Documents_HQ\Fish Passage\ORproj\000\Y12554\Task Order AC\700PROJTEC12_PHD_Working\SR003_MP50-85_SFJohnsonCktoJohnsonCk_991241_CAD_Sheets\XL_xxxx_DE_CD_001.dgn

Appendix E: Manning's Calculations

There are no Manning's Calculations for SF Johnson Creek at SR 3 MP 50.85.

DRAFT

Appendix F: Large Woody Material Calculations

DRAFT

WSDOT Large Woody Material for stream restoration metrics calculator

State Route# & MP	***SR 03 MP50.85***	**Key piece volume**	***1.310***	*yd3*	
Stream name	*SF Johnson Crk*	**Key piece/ft**	***0.0335***	*per ft stream*	
length of regrade[a]	*520* *ft*	**Total wood vol./ft**	***0.3948***	*yd3/ft stream*	
Bankfull width	*7* *ft*	**Total LWM**[c] **pieces/ft stream**	***0.1159***	*per ft stream*	
Habitat zone[b]	*Western WA*				

Taper coeff.	-0.01554
LF_{rw}	1.5
H_{dbh}	4.5

Log type	*Diameter at midpoint (ft)*	*Length(ft)*[d]	*Volume (yd^3 /log)*[d]	*Rootwad?*	*Qualifies as key piece?*	*No. LWM pieces*	*Total wood volume (yd^3)*
A	2.57	*40*	7.69	**yes**	yes	0	0.00
B	2.14	*30*	4.00	**yes**	yes	17	67.94
C	1.70	*20*	1.68	**yes**	yes	0	0.00
D	1.25	*12.5*	0.57	**yes**	no	33	18.75
E	1.20	*10*	0.42	**no**	no	46	19.27
F	0.6	*8*	0.09	**no**	no	0	0.00
G			0.00				0.00
H			0.00				0.00
I			0.00				0.00
J			0.00				0.00
K			0.00				0.00
L			0.00				0.00
M			0.00				0.00
N			0.00				0.00
O			0.00				0.00
P			0.00				0.00

DBH based on mid point diameter (ft)	$D_{root\ collar\ (ft)}$	L/2-Lrw (ft)
	2.82	16.145
2.25	2.32	11.79
	1.82	7.45
1.25	1.32	4.375
1.28	1.25	3.2
	0.66	3.085
	0.00	0
	0.00	0
	0.00	0
	0.00	0
	0.00	0
	0.00	0
	0.00	0
	0.00	0
	0.00	0
	0.00	0

	No. of key pieces	**Total No. of LWM pieces**	**Total LWM volume (yd^3)**
Design	17	96	106.0
Targets	**17**	**60**	**205.3**
	on target	surplus	deficit

[a] **includes length through crossing, regardless of structure type**

[b] **choose one of the following Forest Regions in the drop-down menu (if in doubt ask HQ Biology). See also the Forest Region tab for additional information**

Western Washington lowl (generally <4,200 ft. in elevation west of the Cascade Crest)
Alpine (generally > 4,200 ft. in elevation and down to ~3,700 ft. in elevation east of the Cascade crest)
Douglas fir-Ponderosa pin (mainly east slope Cascades below 3,700 ft. elevation)

[c] **LWM (Large Woody Material), also known as LWD (Large Woody Debris) is defined as a piece of wood at least 10 cm (4") diam. X 2 m (6ft) long (Fox 2001).**

[d] **includes rootwad if present**

Key piece volume

BFW class (ft)	volume (yd3)
0-16	1.31
17-33	3.28
34-49	7.86
50-66	11.79
67-98	12.77
99-164	13.76
165-328	14.08

adapted from Fox and Bolton (2007), Table 5

Key Piece density lookup table

Habitat zone	BFW class (feet)	75th percentile (yd3/ft stream)
Western WA	0-33	0.0335
	34-328	0.0122
Alpine	0-49	0.0122
	50-164	0.0030
Douglas Fir/Pond. Pine (much of eastern WA)	0-98	0.0061

adapted from Fox and Bolton (2007), Table 4

Total Wood Volume lookup table

Habitat zone	BFW class (feet)	75th percentile (yd3/ft stream)
Western WA	0-98	0.3948
	99-328	1.2641
Alpine	0-10	0.0399
	11-164	0.1196
Douglas Fir/Pond. Pine	0-98	0.0598

adapted from Fox and Bolton (2007), Table 4

Number of LWM pieces lookup table

Habitat zone	BFW class (feet)	75th percentile (per/ft stream)
Western WA	0-20	0.1159
	21-98	0.1921
	99-328	0.6341
Alpine	0-10	0.0854
	11-98	0.1707
	99-164	0.1921
Douglas Fir/Pond. Pine	0-20	0.0884
	21-98	0.1067

adapted from Fox and Bolton (2007), Table 4

Appendix G: Future Projections for Climate-Adapted Culvert Design

DRAFT

Future Projections for Climate-Adapted Culvert Design

Project Name: 991241

Stream Name: SF Johnson Creek

Drainage Area: 100 ac

Projected mean percent change in bankfull flow:

2040s: 14.4%

2080s: 17.4%

Projected mean percent change in bankfull width:

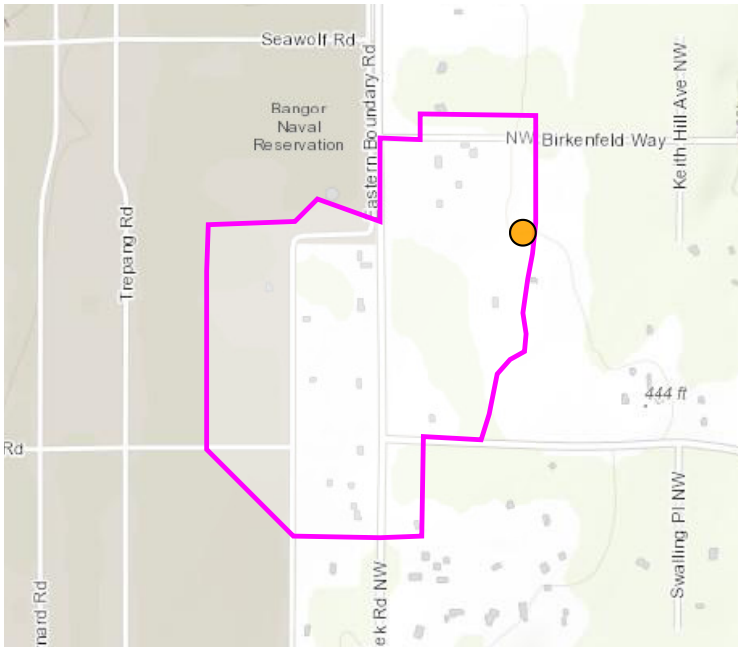
2040s: 6.9%

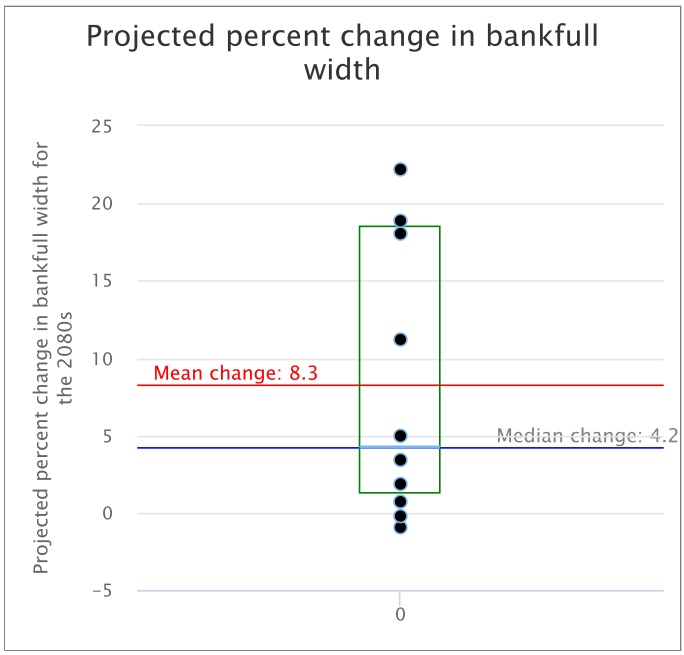
2080s: 8.3%

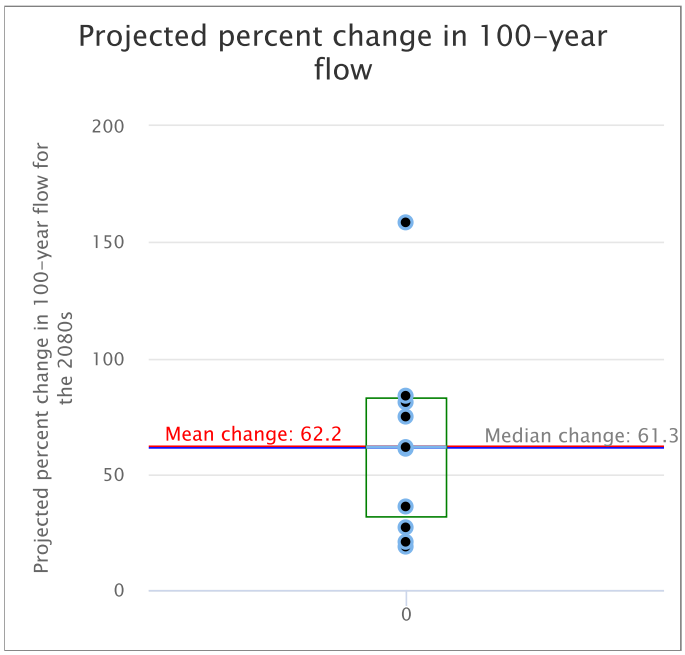
Projected mean percent change in 100-year flood:

2040s: 45.2%

2080s: 62.2%



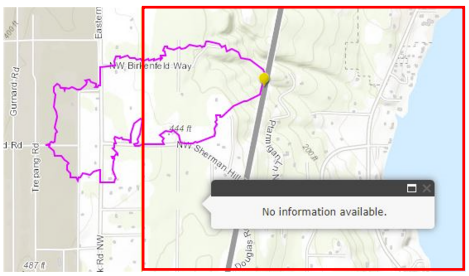




Black dots are projections from 10 separate models

The Washington Department of Fish and Wildlife makes no guarantee concerning the data's content, accuracy, precision, or completeness. WDFW makes no warranty of fitness for a particular purpose and assumes no liability for the data represented here.

Note: The Culverts and Climate Change app calculates projections based on gridded data. Where watersheds intersect multiple grid cells, the weighted average is calculated. The watershed for this site spans an empty grid cell and a grid cell with data. Reports cannot be exported for grid cells with no data, therefore this report is generated from a reduced watershed developed in the grid cell with data. The area in the report is not representative of the area of the site basin, but the reduction in area does not affect the projections in the report



Appendix H: SRH-2D Model Results

DRAFT

Figure List

Plan View Results – Existing Conditions

1 Existing Conditions – Q2 Water Surface Elevation (ft, NAVD 88)
2 Existing Conditions – Q100 Water Surface Elevation (ft, NAVD 88)
3 Existing Conditions – Q500 Water Surface Elevation (ft, NAVD 88)
4 Existing Conditions – Q2 Depth (ft)
5 Existing Conditions – Q100 Depth (ft)
6 Existing Conditions – Q500 Depth (ft)
7 Existing Conditions – Q2 Velocity Magnitude (ft/s)
8 Existing Conditions – Q100 Velocity Magnitude (ft/s)
9 Existing Conditions – Q500 Velocity Magnitude (ft/s)
10 Existing Conditions – Q2 Shear Stress (psf)
11 Existing Conditions – Q100 Shear Stress (psf)
12 Existing Conditions – Q500 Shear Stress (psf)

Plan View Results – Proposed Conditions

13 Proposed Conditions – Q2 Water Surface Elevation (ft, NAVD 88)
14 Proposed Conditions – Q100 Water Surface Elevation (ft, NAVD 88)
15 Proposed Conditions – Q500 Water Surface Elevation (ft, NAVD 88))
16 Proposed Conditions – 2080 Projected Q100 Water Surface Elevation (ft, NAVD 88)
17 Proposed Conditions – Q2 Depth (ft)
18 Proposed Conditions – Q100 Depth (ft)
19 Proposed Conditions – Q500 Depth (ft)
20 Proposed Conditions –Projected 2080 Q100 Depth (ft)
21 Proposed Conditions – Q2 Velocity Magnitude (ft/s)
22 Proposed Conditions – Q100 Velocity Magnitude (ft/s)
23 Proposed Conditions – Q500 Velocity Magnitude (ft/s)
24 Proposed Conditions –Projected 2080 Q100 Velocity Magnitude (ft/s)
25 Proposed Conditions – Q2 Shear Stress (psf)
26 Proposed Conditions – Q100 Shear Stress (psf)
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28 Proposed Conditions –Projected 2080 Shear Stress (psf)

Longitudinal Profile Results

29 Existing Conditions - Longitudinal Profile – Water Surface Elevation (ft, NAVD 88)
30 Proposed Conditions - Longitudinal Profile – Water Surface Elevation (ft, NAVD 88)

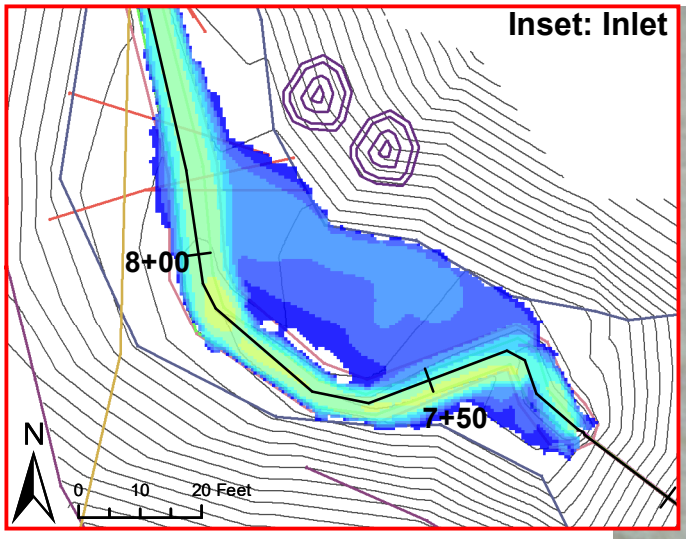
Cross-Section Results

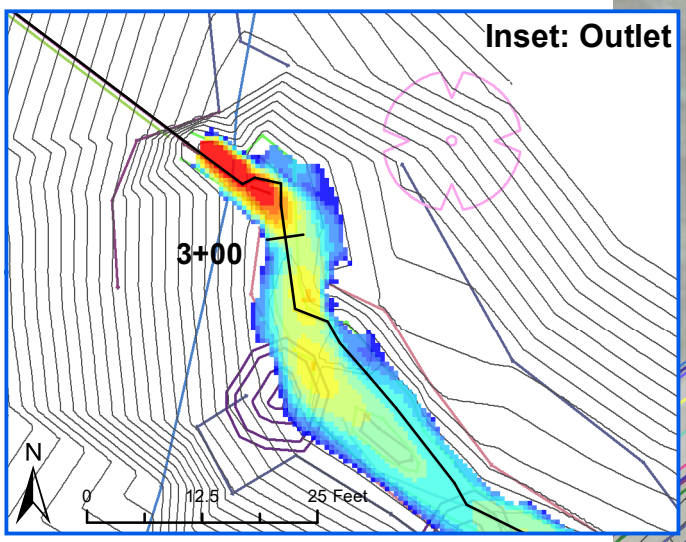
31 Existing Conditions – Downstream Cross Section 13 at STA 0+74
31 Proposed Conditions – Downstream Cross Section 13 at STA 0+74
32 Existing Conditions – Downstream Cross Section 11 at STA 1+20
32 Proposed Conditions – Downstream Cross Section 11 at STA 1+20
33 Existing Conditions – Downstream Cross Section 3 at STA 2+47
33 Proposed Conditions – Downstream Cross Section 3 at STA 2+47
34 Existing Conditions – Upstream Cross Section 2 at STA 8+53
34 Proposed Conditions – Upstream Cross Section 2 at STA 8+53
35 Existing Conditions – Upstream Cross Section 3 at STA 8+64
35 Proposed Conditions – Upstream Cross Section 3 at STA 8+64
36 Existing Conditions – Upstream Cross Section 4 at STA 9+07
36 Proposed Conditions – Upstream Cross Section 4 at STA 9+07
37 Proposed Conditions – Crossing Section at STA 7+22

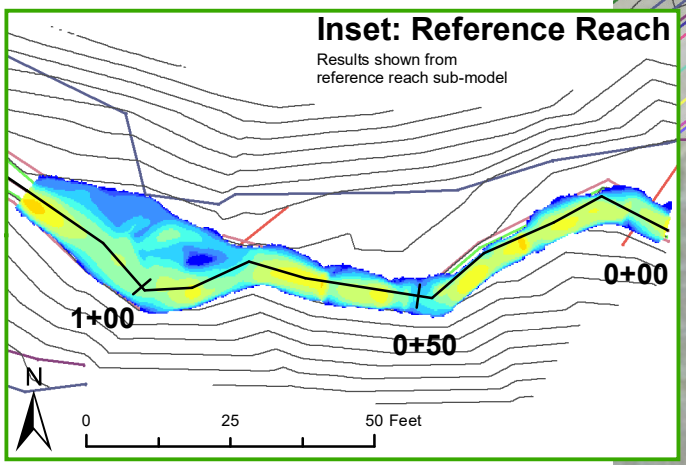
Appendix H

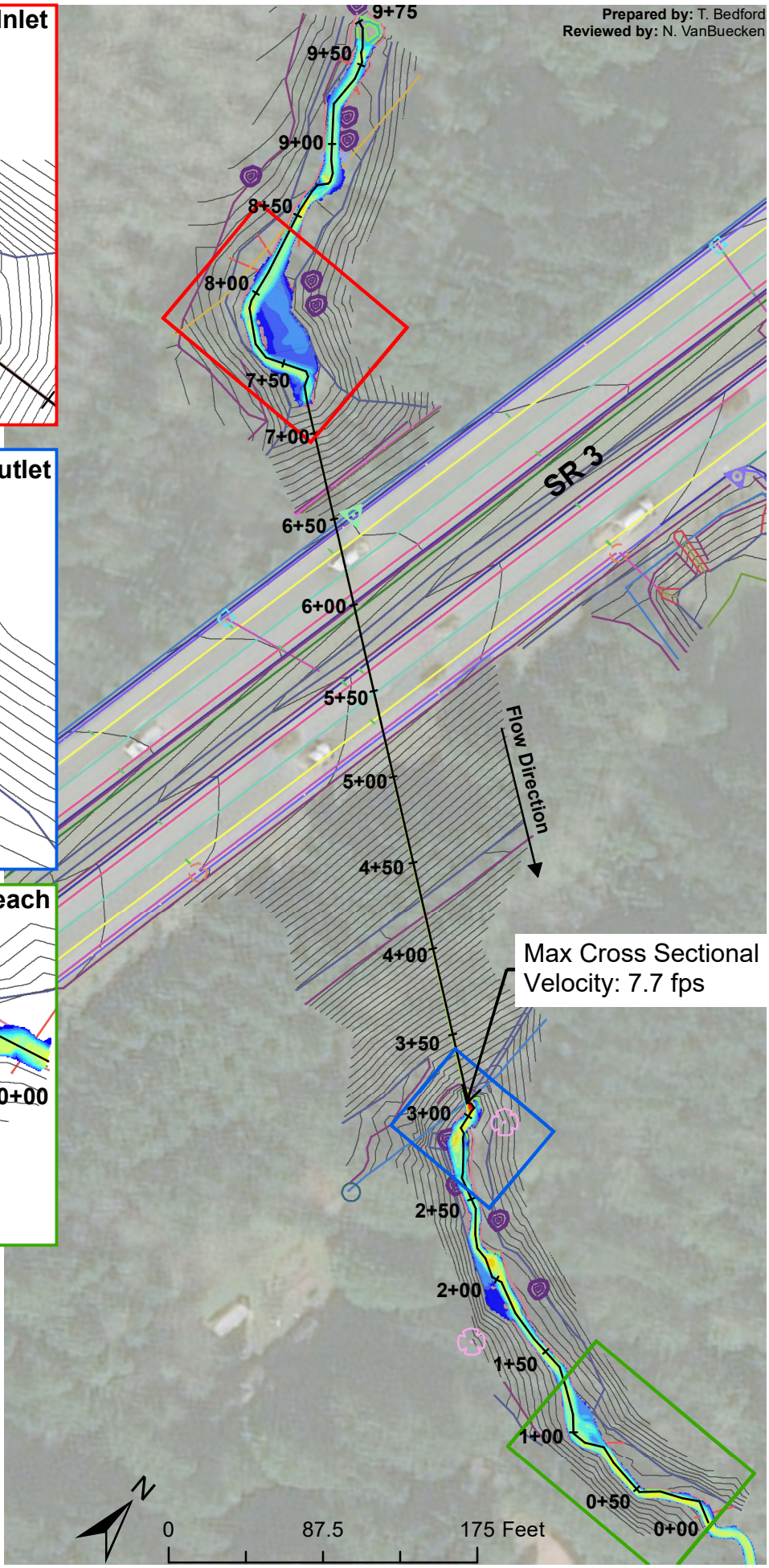
SR 3 MP 50.85 SF Johnson Creek - Model Outputs

Prepared by: T. Bedford
Reviewed by: N. VanBuecken









Existing Conditions, 2yr Velocity

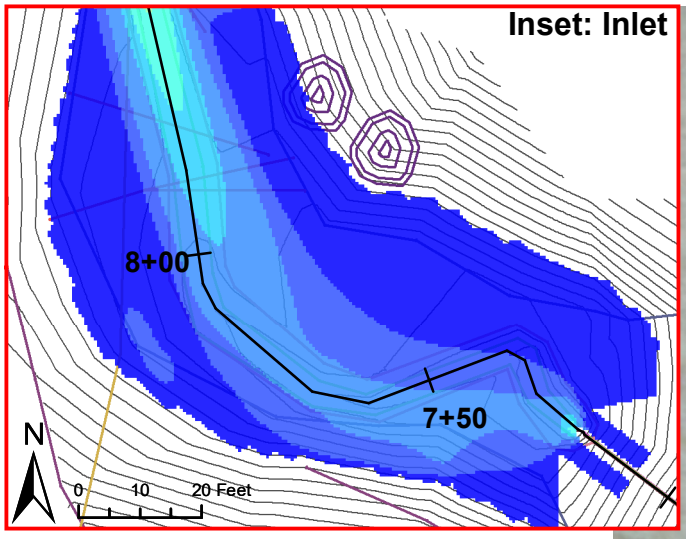
Velocity (fps)

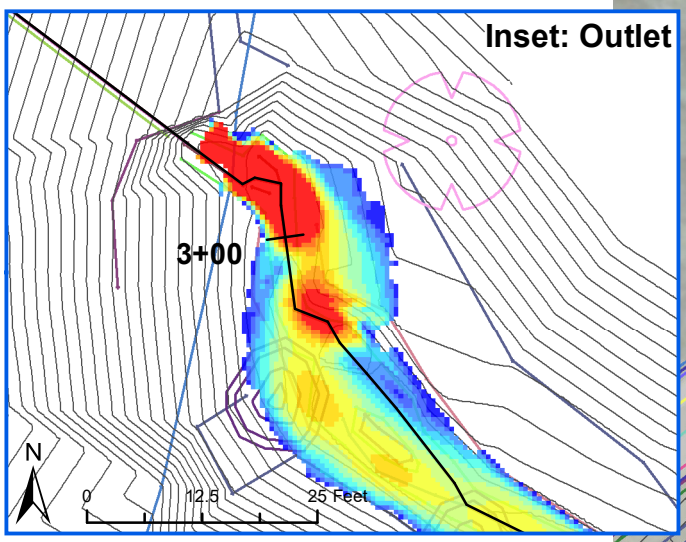
< 0.25	2.0 - 3	6.0 - 7
0.25 - 0.5	3.0 - 4	7.0 - 8
0.5 - 1	4.0 - 5	8.0 - 9
1.0 - 2	5.0 - 6	

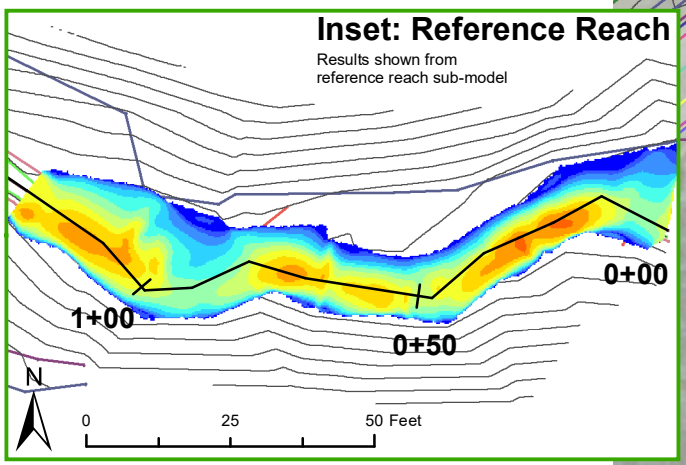
Appendix H

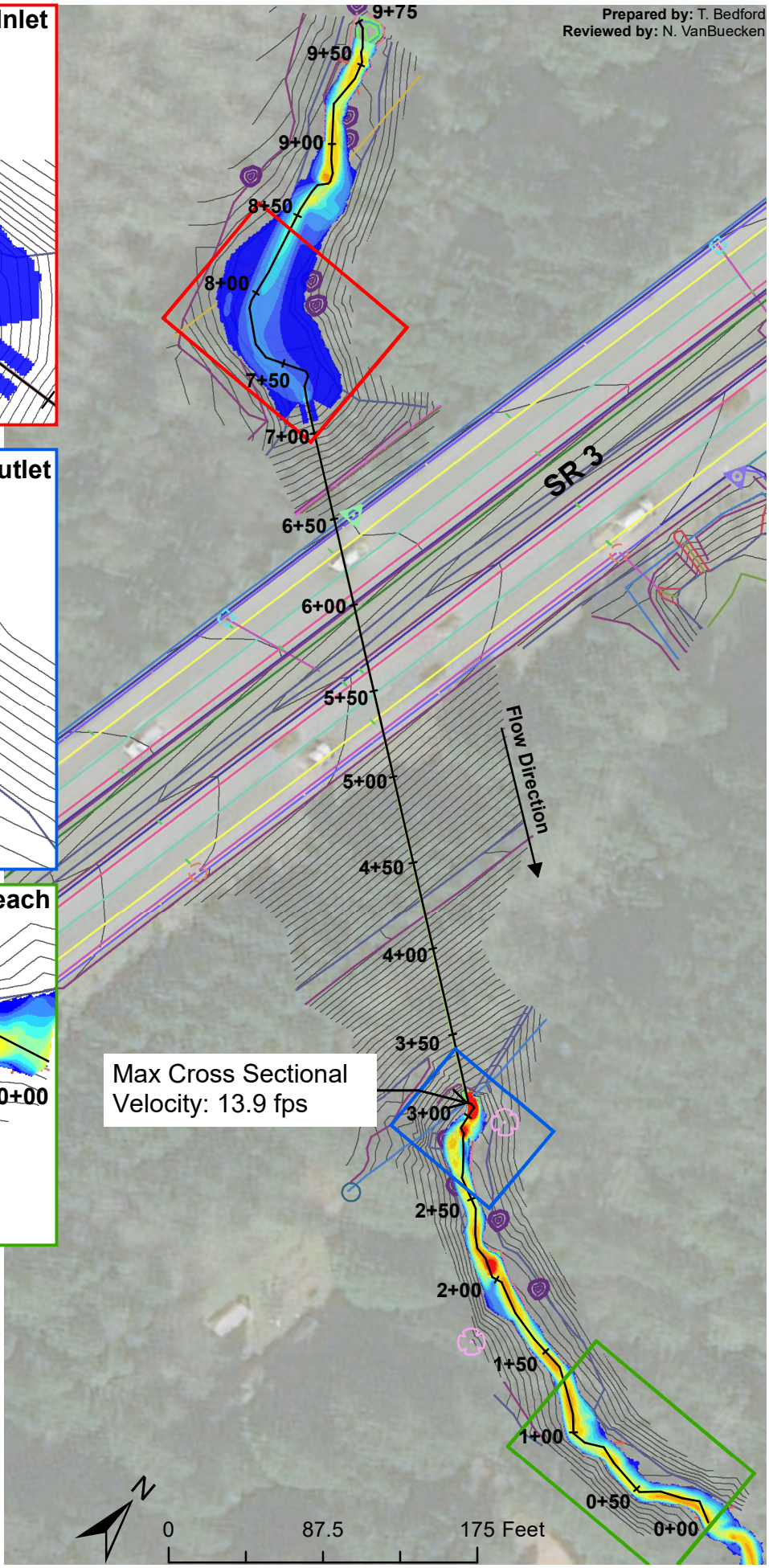
SR 3 MP 50.85 SF Johnson Creek - Model Outputs

Prepared by: T. Bedford
Reviewed by: N. VanBuecken









Existing Conditions, 100yr Velocity

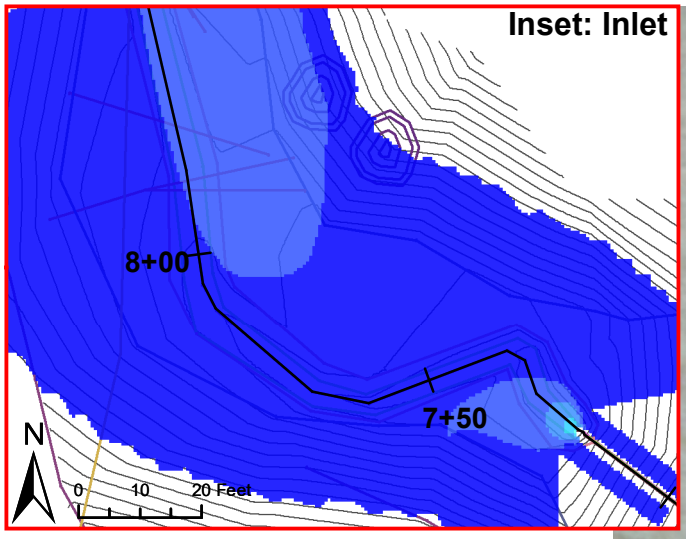
Velocity (fps)

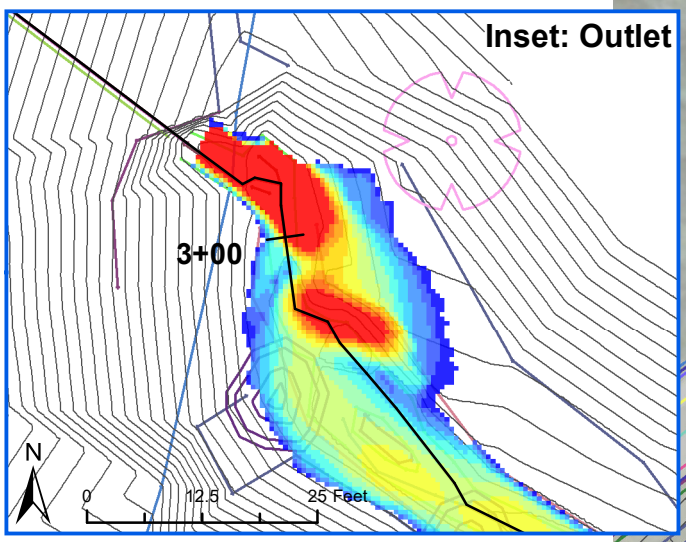
< 0.25	2.0 - 3	6.0 - 7
0.25 - 0.5	3.0 - 4	7.0 - 8
0.5 - 1	4.0 - 5	8.0 - 9
1.0 - 2	5.0 - 6	

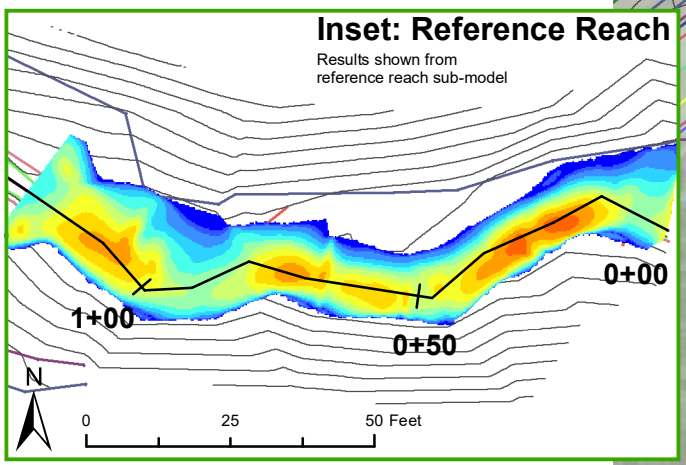
Appendix H

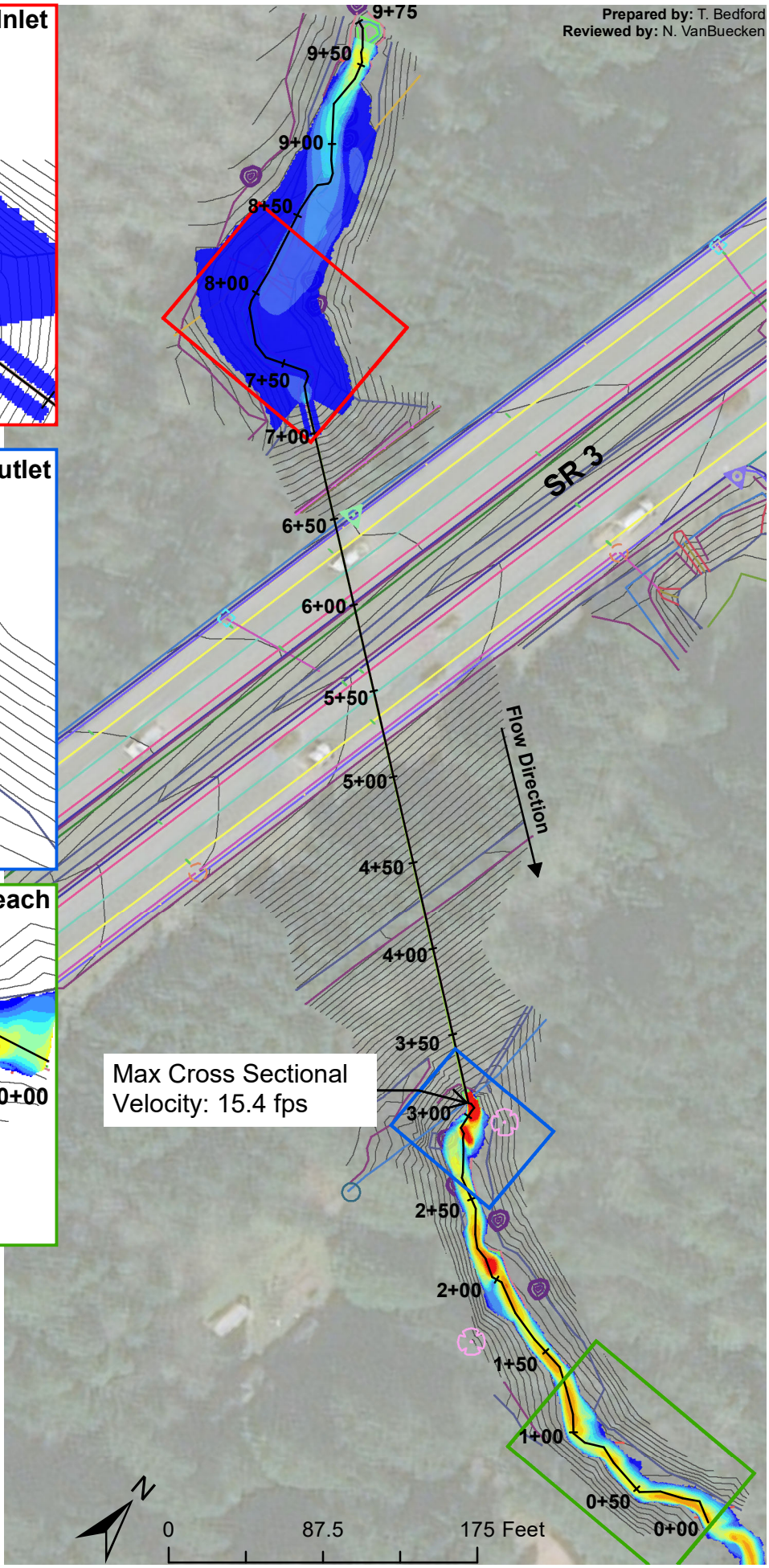
SR 3 MP 50.85 SF Johnson Creek - Model Outputs

Prepared by: T. Bedford
Reviewed by: N. VanBuecken









Existing Conditions, 500yr Velocity

Velocity (fps)

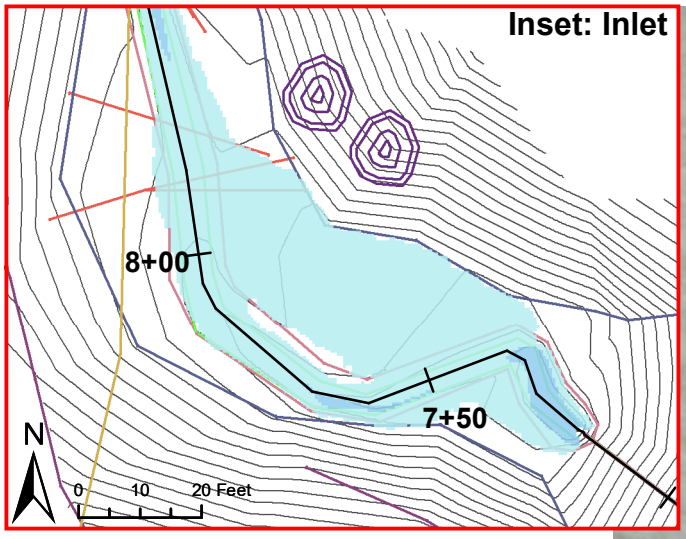
< 0.25	2.0 - 3	6.0 - 7
0.25 - 0.5	3.0 - 4	7.0 - 8
0.5 - 1	4.0 - 5	8.0 - 9
1.0 - 2	5.0 - 6	

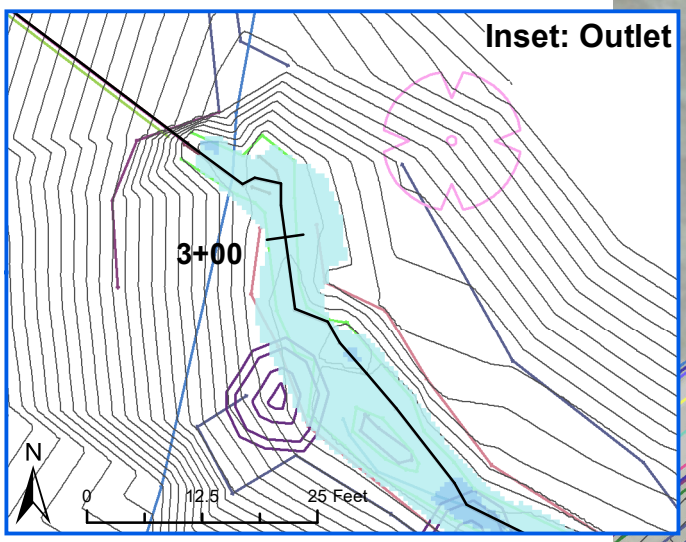
WSDOT OLYMPIC REGION GEC

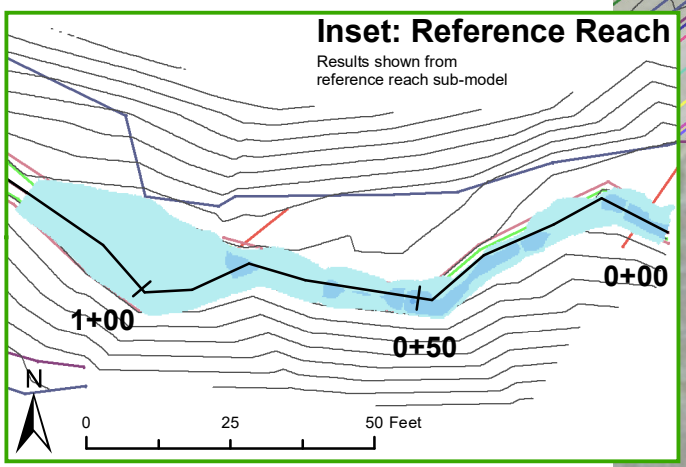
Appendix H

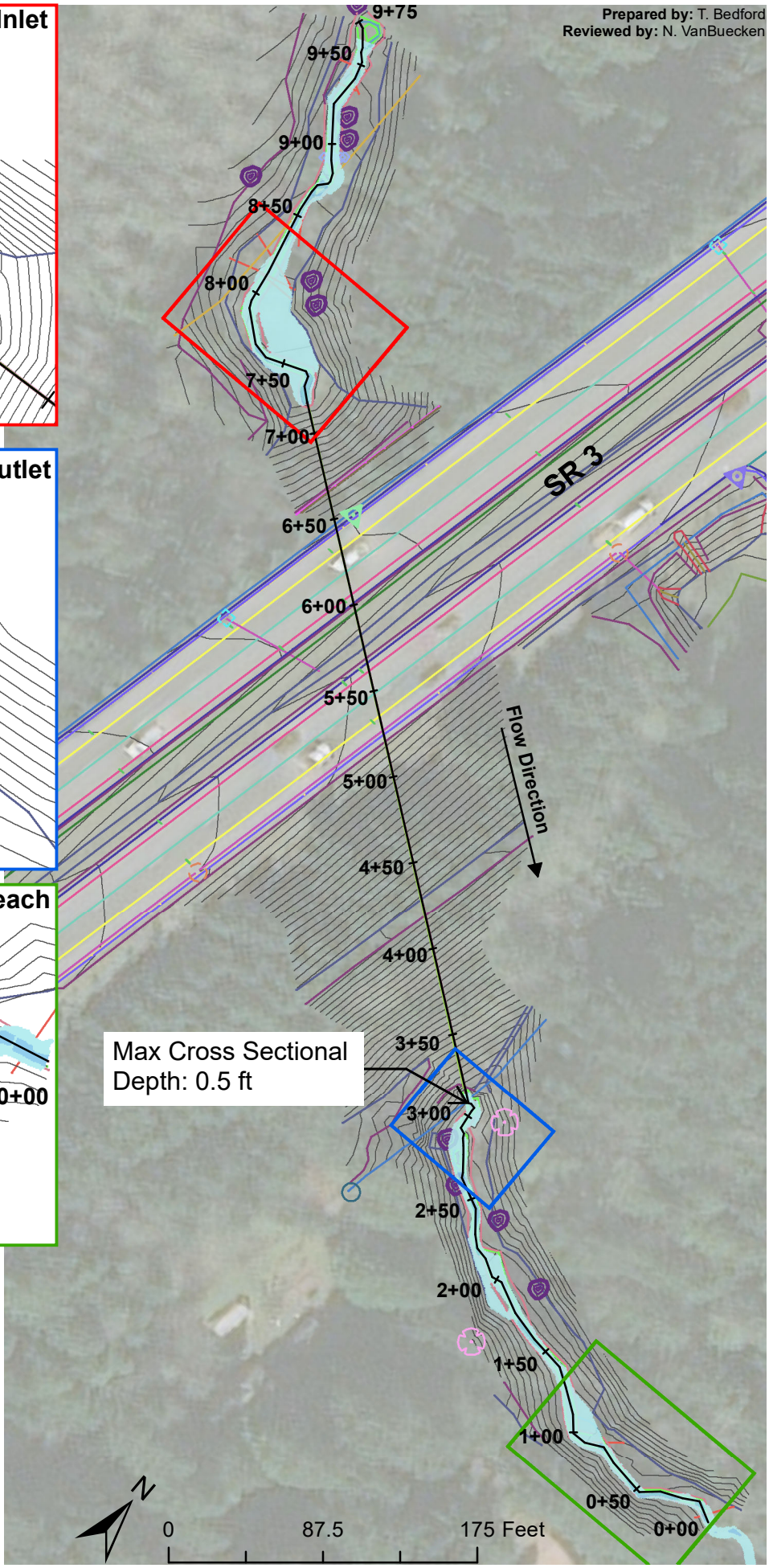
SR 3 MP 50.85 SF Johnson Creek - Model Outputs

Prepared by: T. Bedford
Reviewed by: N. VanBuecken









Existing Conditions, 2yr Depth

Depth (ft)

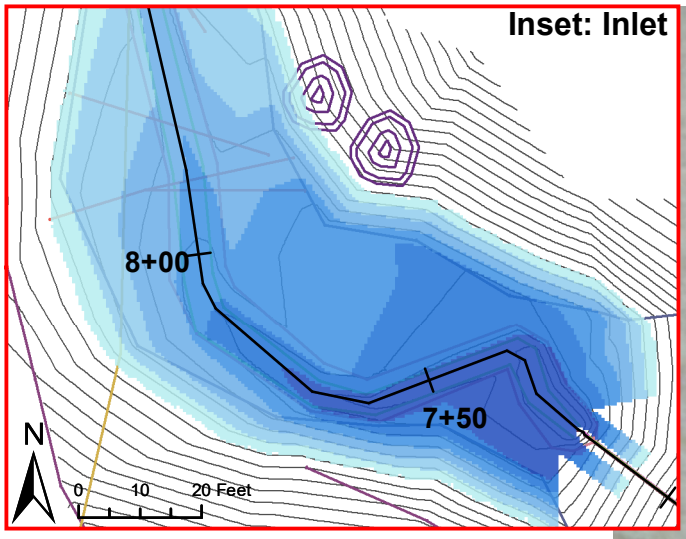
< 1	3.0 - 4	10.0 - 15
1.0 - 2	4.0 - 5	> 15.0
2.0 - 3	5.0 - 10	

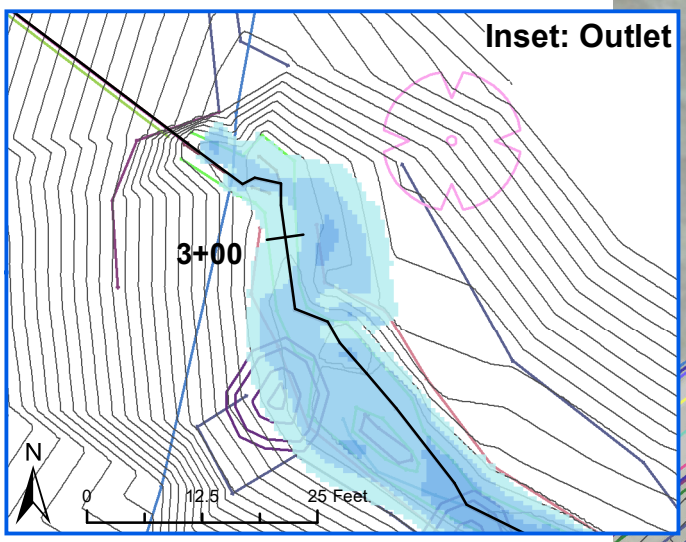
WSDOT OLYMPIC REGION GEC

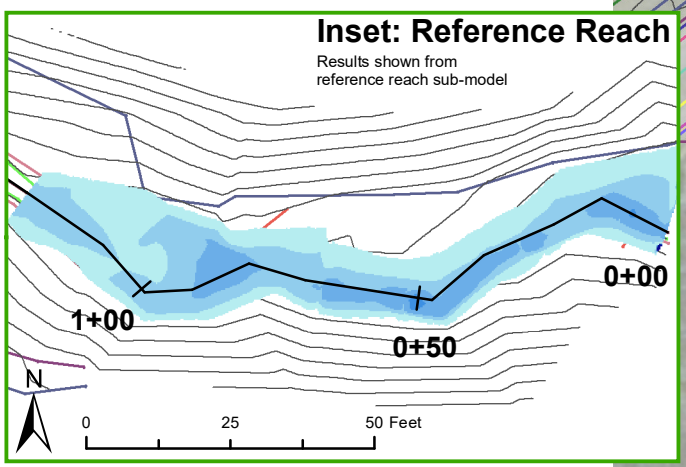
Appendix H

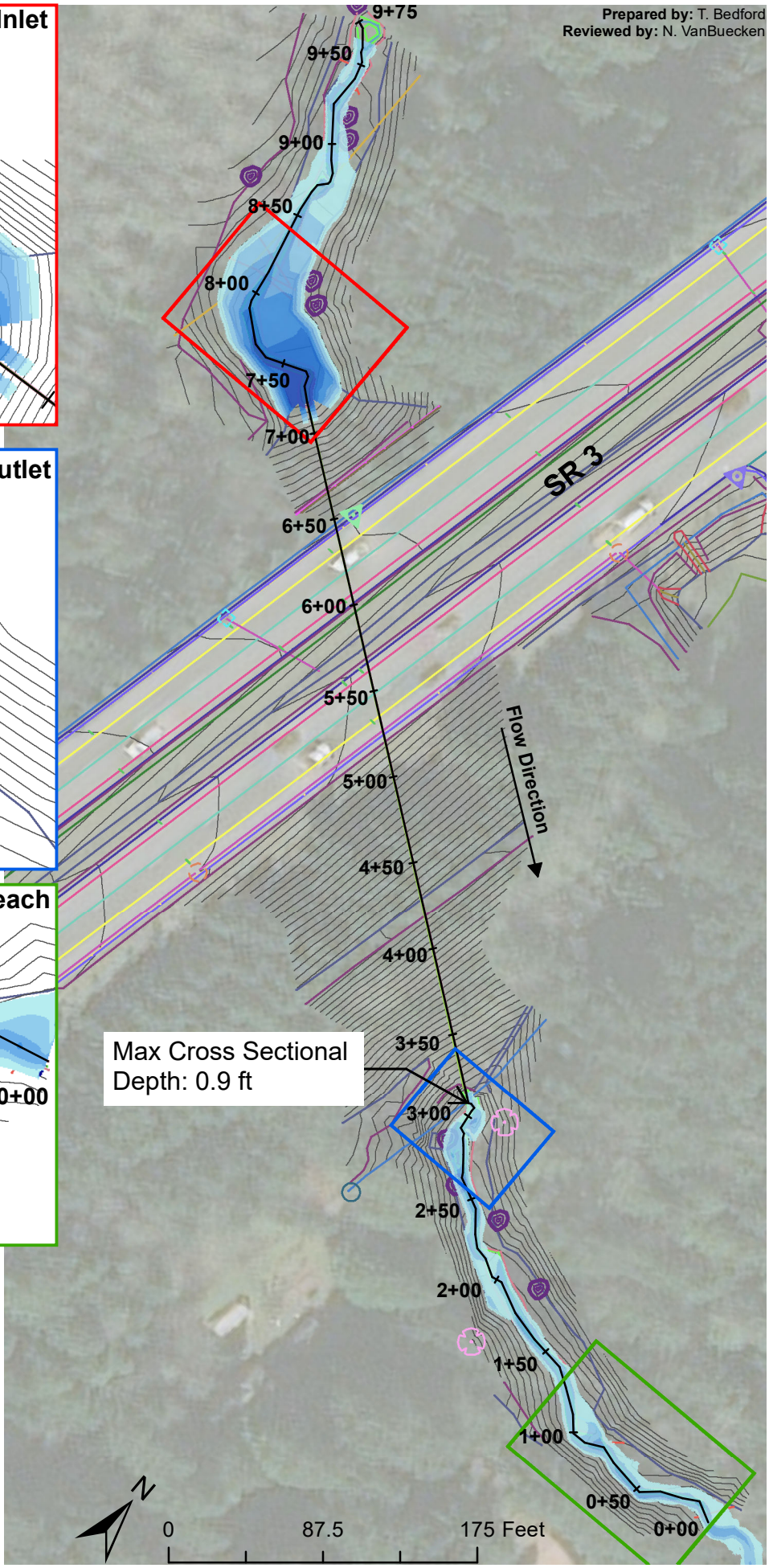
SR 3 MP 50.85 SF Johnson Creek - Model Outputs

Prepared by: T. Bedford
Reviewed by: N. VanBuecken









Existing Conditions, 100yr Depth

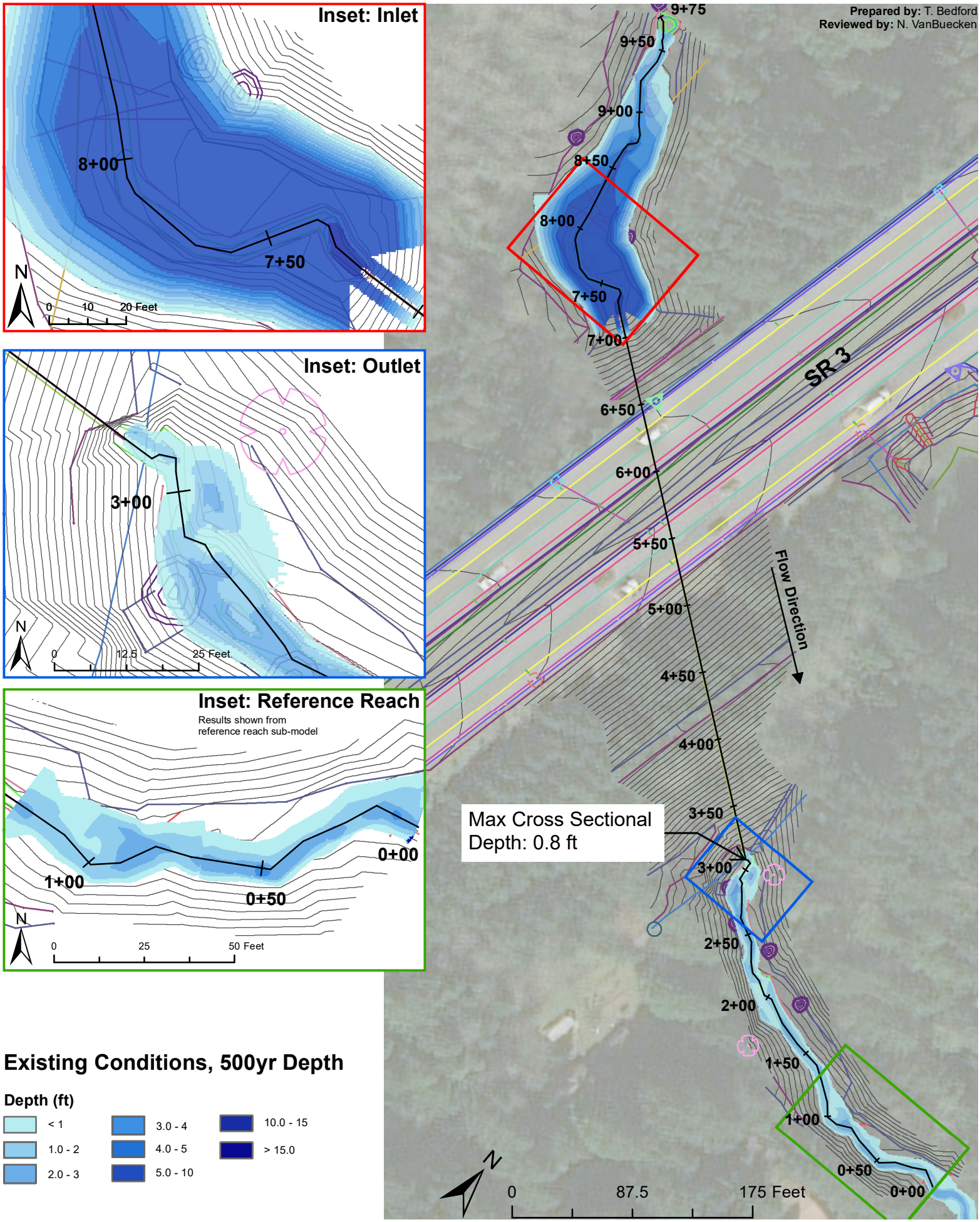
Depth (ft)

< 1	3.0 - 4	10.0 - 15
1.0 - 2	4.0 - 5	> 15.0
2.0 - 3	5.0 - 10	

WSDOT OLYMPIC REGION GEC

Appendix H

SR 3 MP 50.85 SF Johnson Creek - Model Outputs



Existing Conditions, 500yr Depth

Depth (ft)

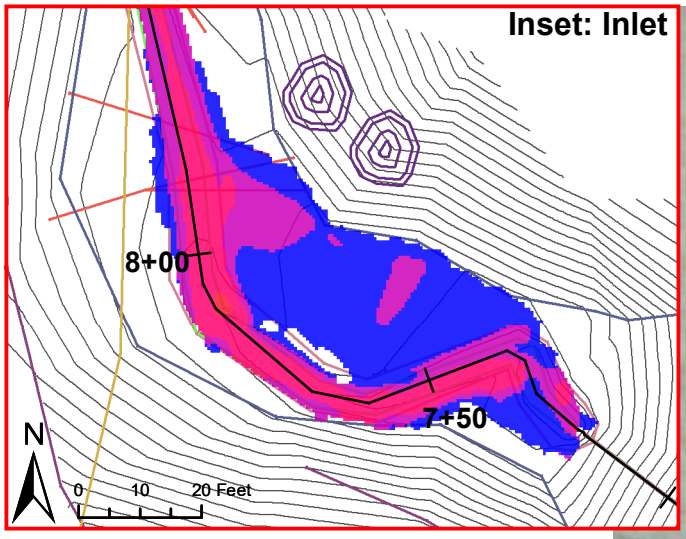
- < 1
- 1.0 - 2
- 2.0 - 3
- 3.0 - 4
- 4.0 - 5
- 5.0 - 10
- 10.0 - 15
- > 15.0

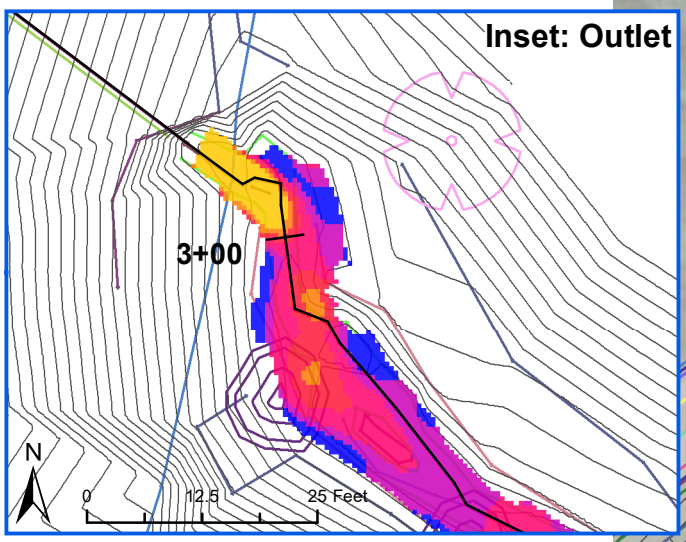
WSDOT OLYMPIC REGION GEC

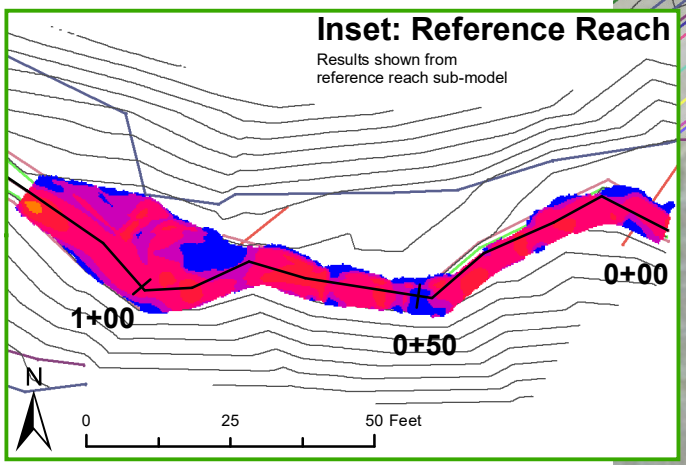
Appendix H

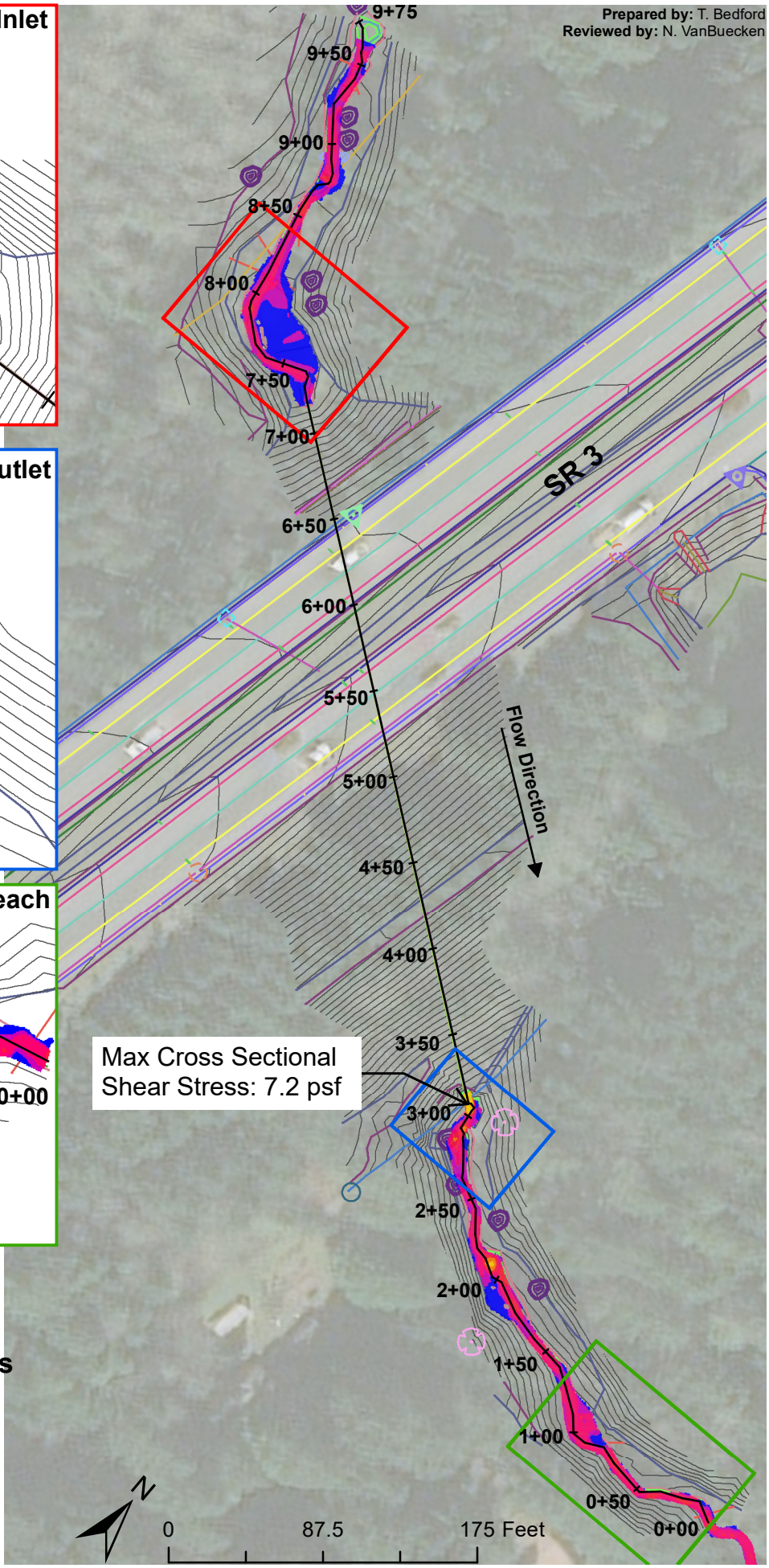
SR 3 MP 50.85 SF Johnson Creek - Model Outputs

Prepared by: T. Bedford
Reviewed by: N. VanBuecken









Existing Conditions, 2yr Shear Stress

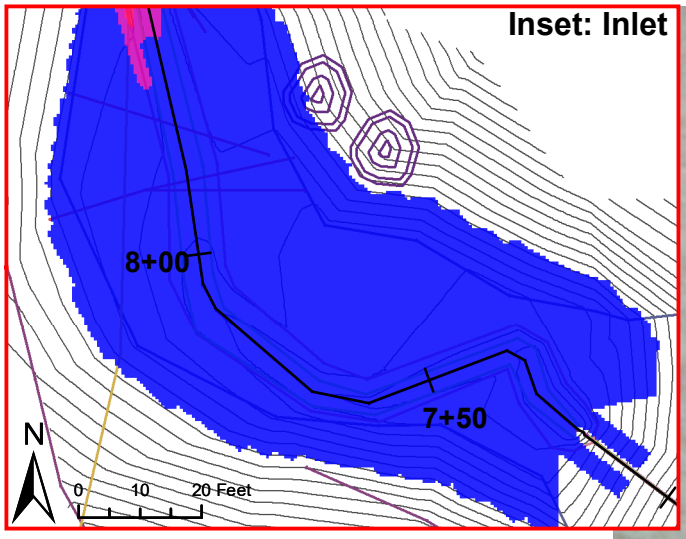
Shear Stress (psf)

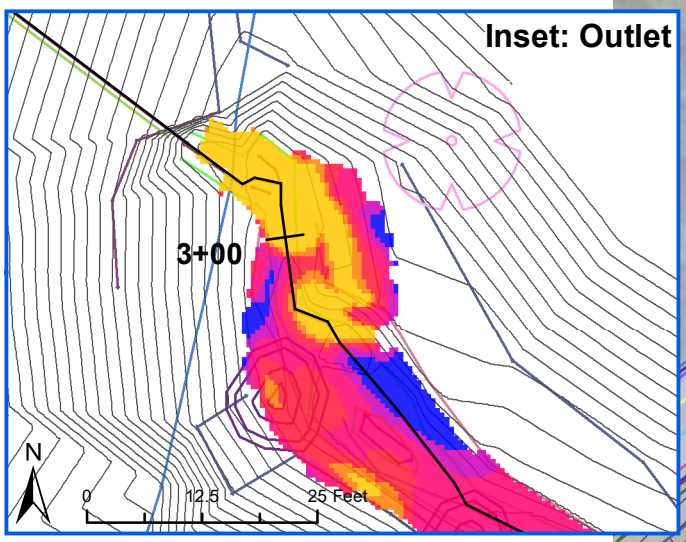
- 0 - 0.5
- 0.5 - 1.0
- 1.0 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0
- > 4.0

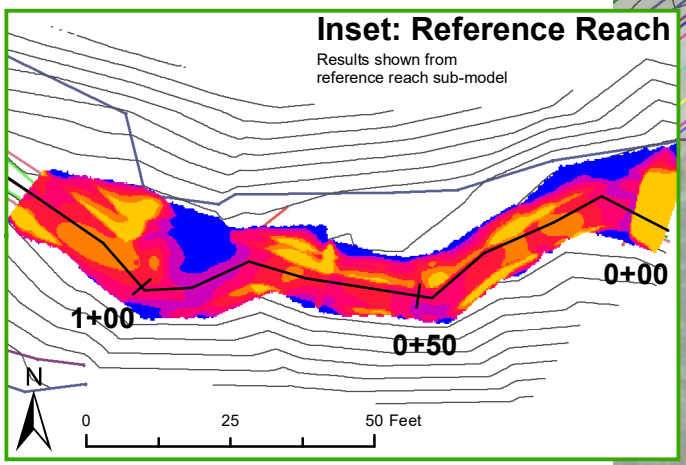
Appendix H

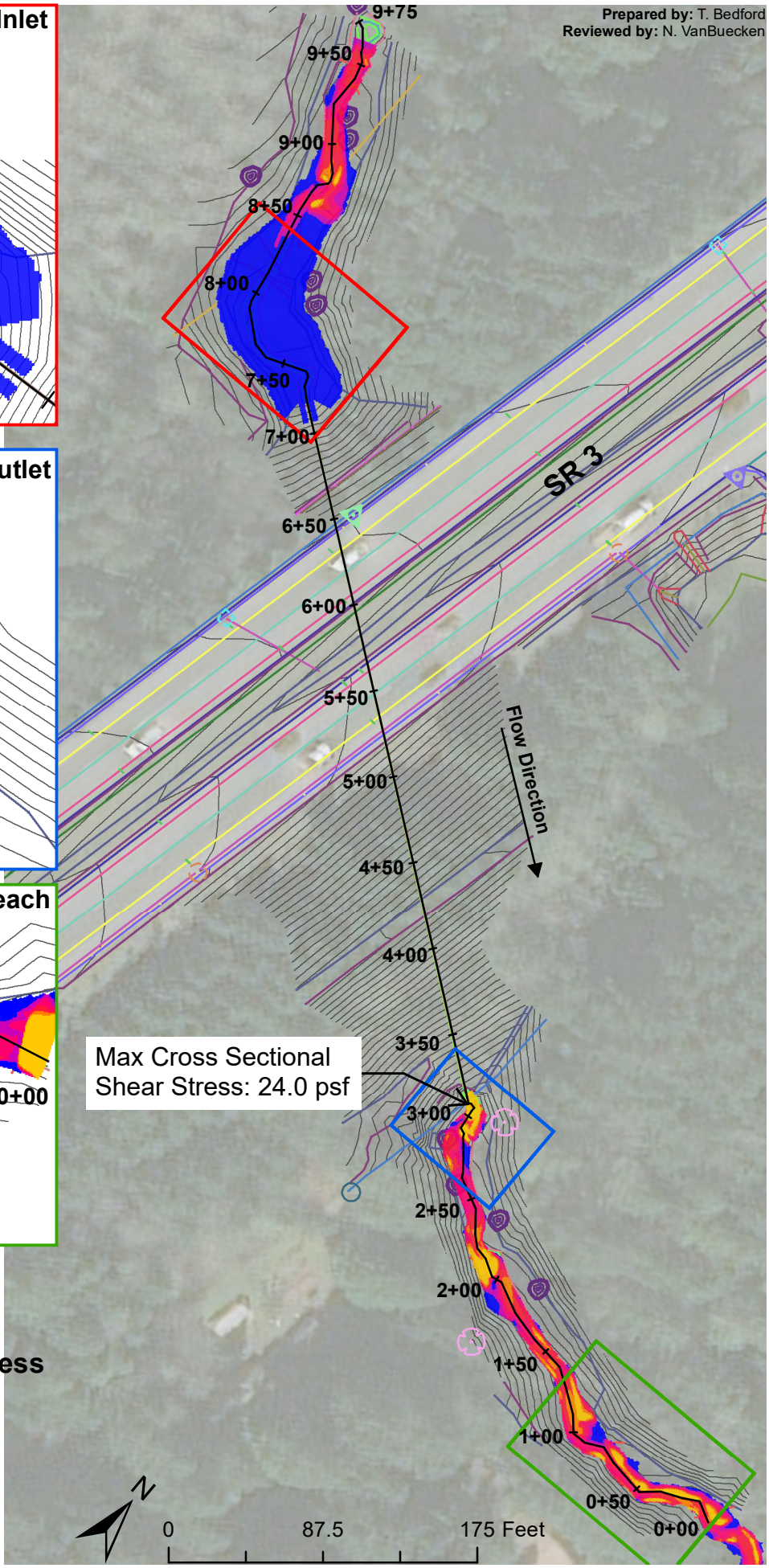
SR 3 MP 50.85 SF Johnson Creek - Model Outputs

Prepared by: T. Bedford
Reviewed by: N. VanBuecken









Existing Conditions, 100yr Shear Stress

Shear Stress (psf)

0 - 0.5	2.0 - 3.0
0.5 - 1.0	3.0 - 4.0
1.0 - 2.0	> 4.0

Appendix H

SR 3 MP 50.85 SF Johnson Creek - Model Outputs

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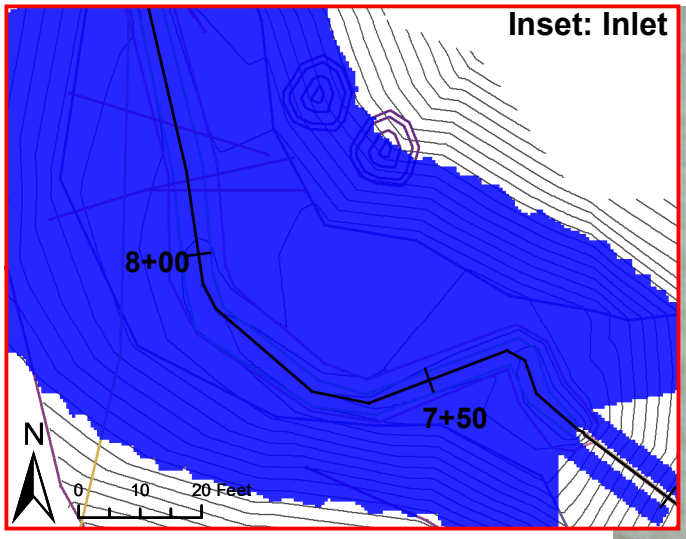

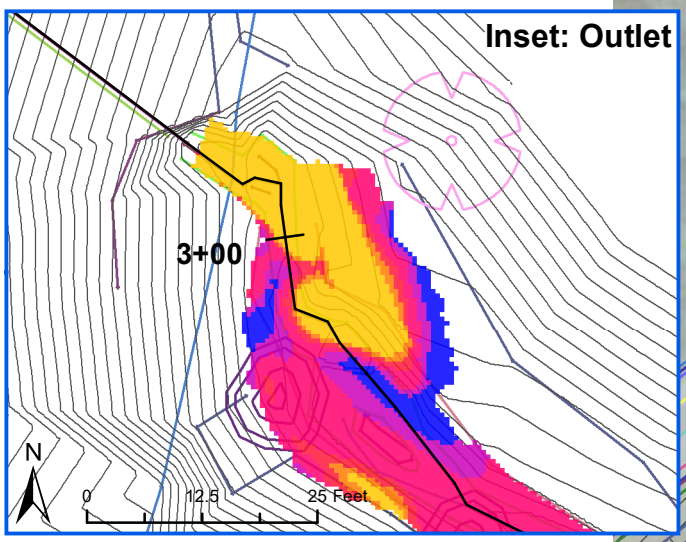

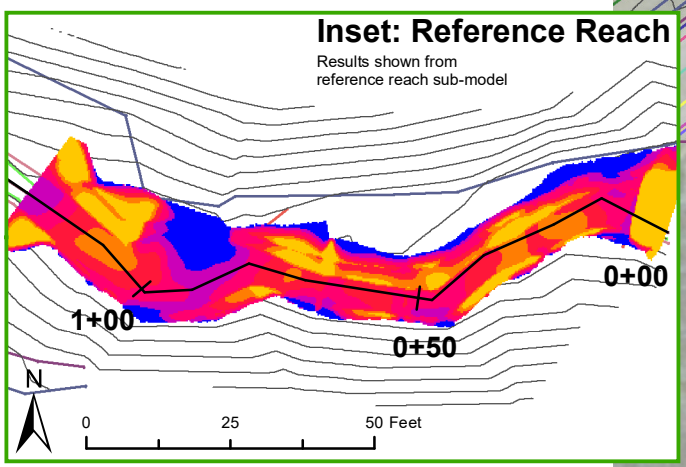

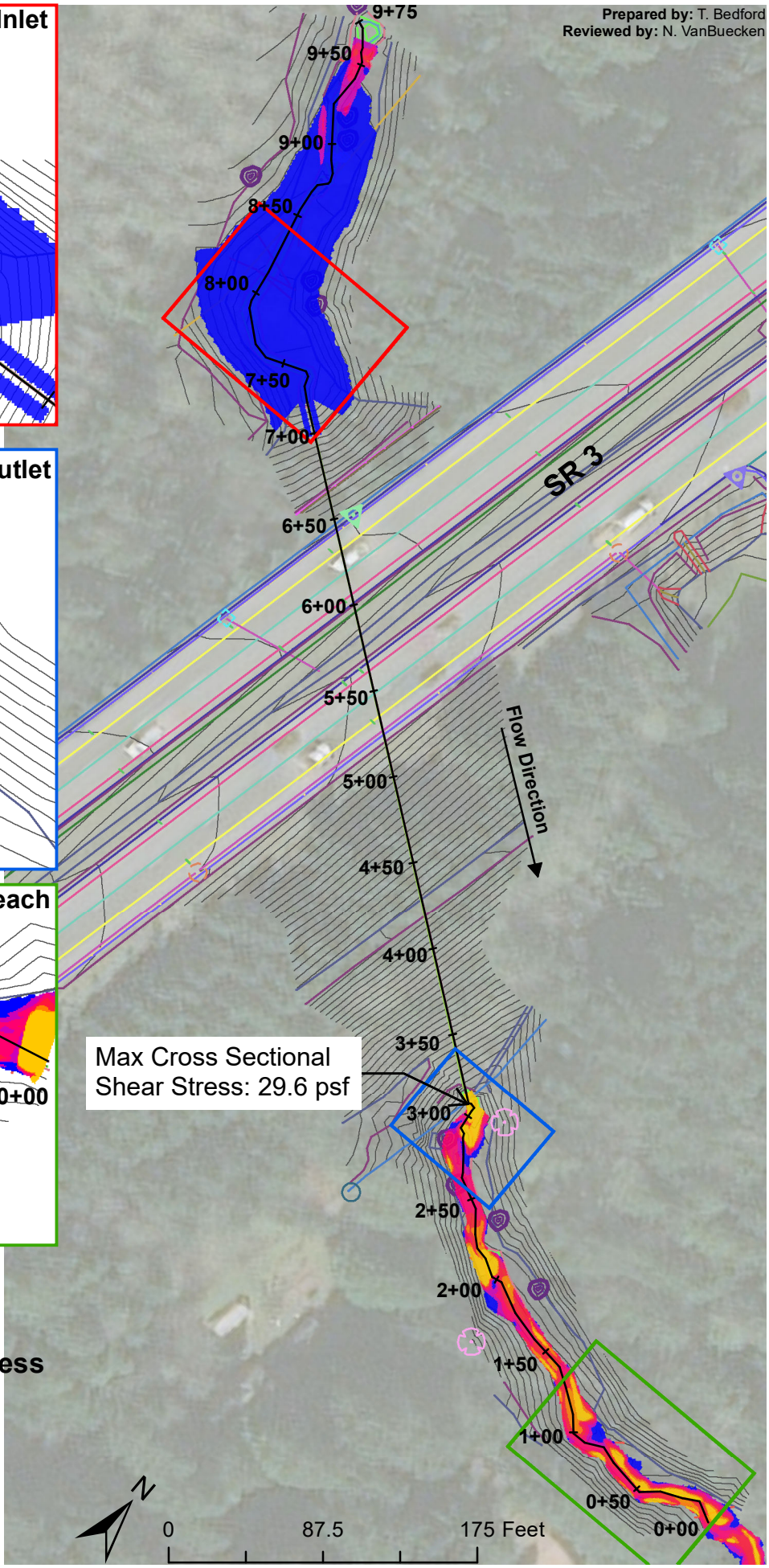

Existing Conditions, 500yr Shear Stress

Shear Stress (psf)

- 0 - 0.5
- 0.5 - 1.0
- 1.0 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0
- > 4.0

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SR 3 MP 50.85 SF Johnson Creek - Model Outputs

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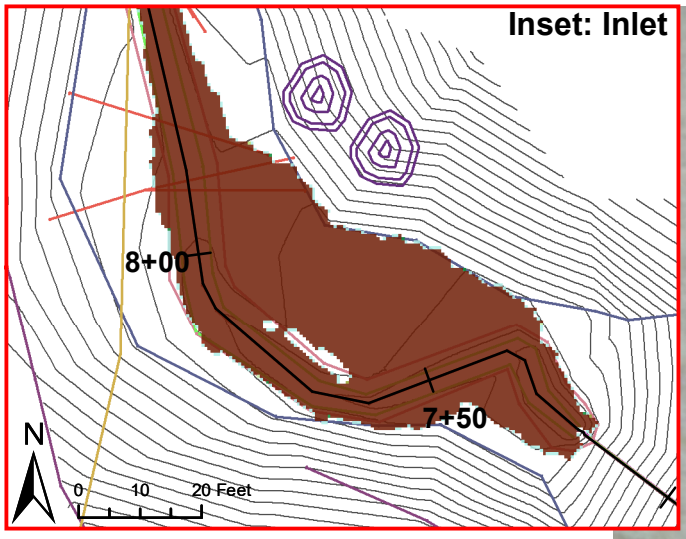
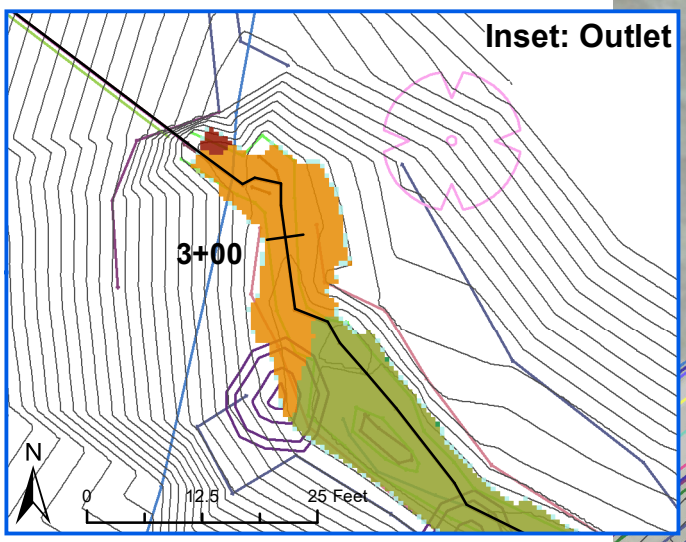
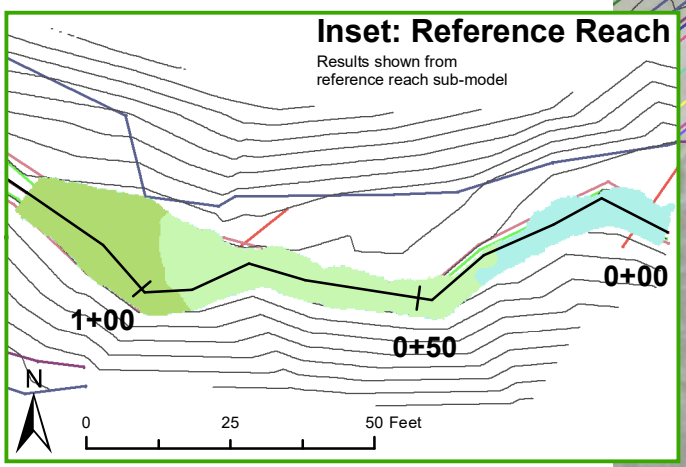
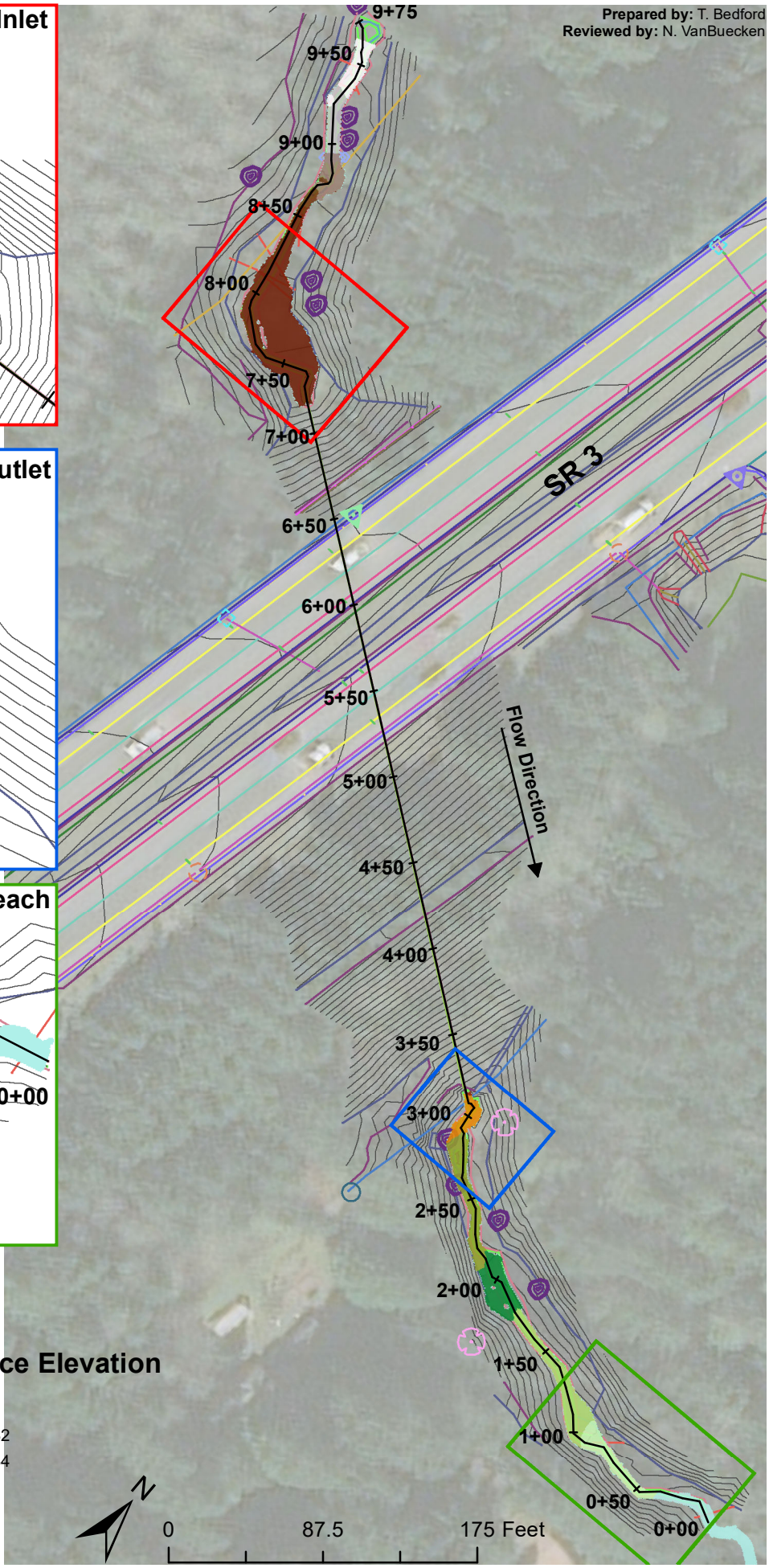
Reviewed by: N. VanBuecken









Existing Conditions, 2yr Water Surface Elevation

Water Surface Elevation (ft, NAVD '88)

< 178	184.0 - 187	193.0 - 196	230.0 - 232
178.0 - 181	187.0 - 190	196.0 - 228	232.0 - 234
181.0 - 184	190.0 - 193	228.0 - 230	> 234

Appendix H

SR 3 MP 50.85 SF Johnson Creek - Model Outputs

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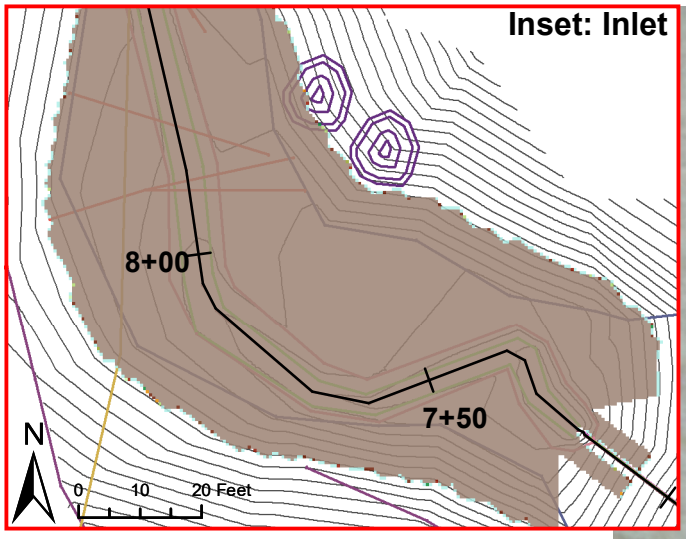
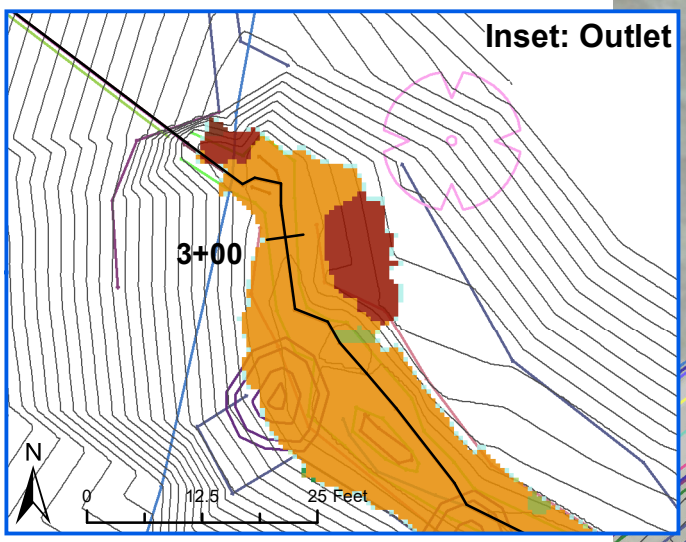
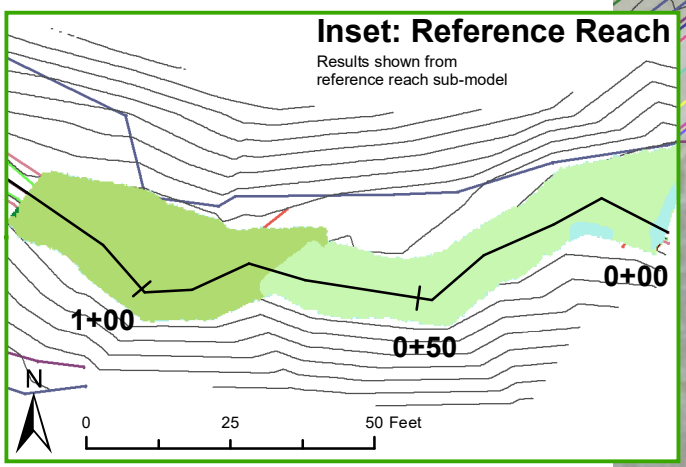
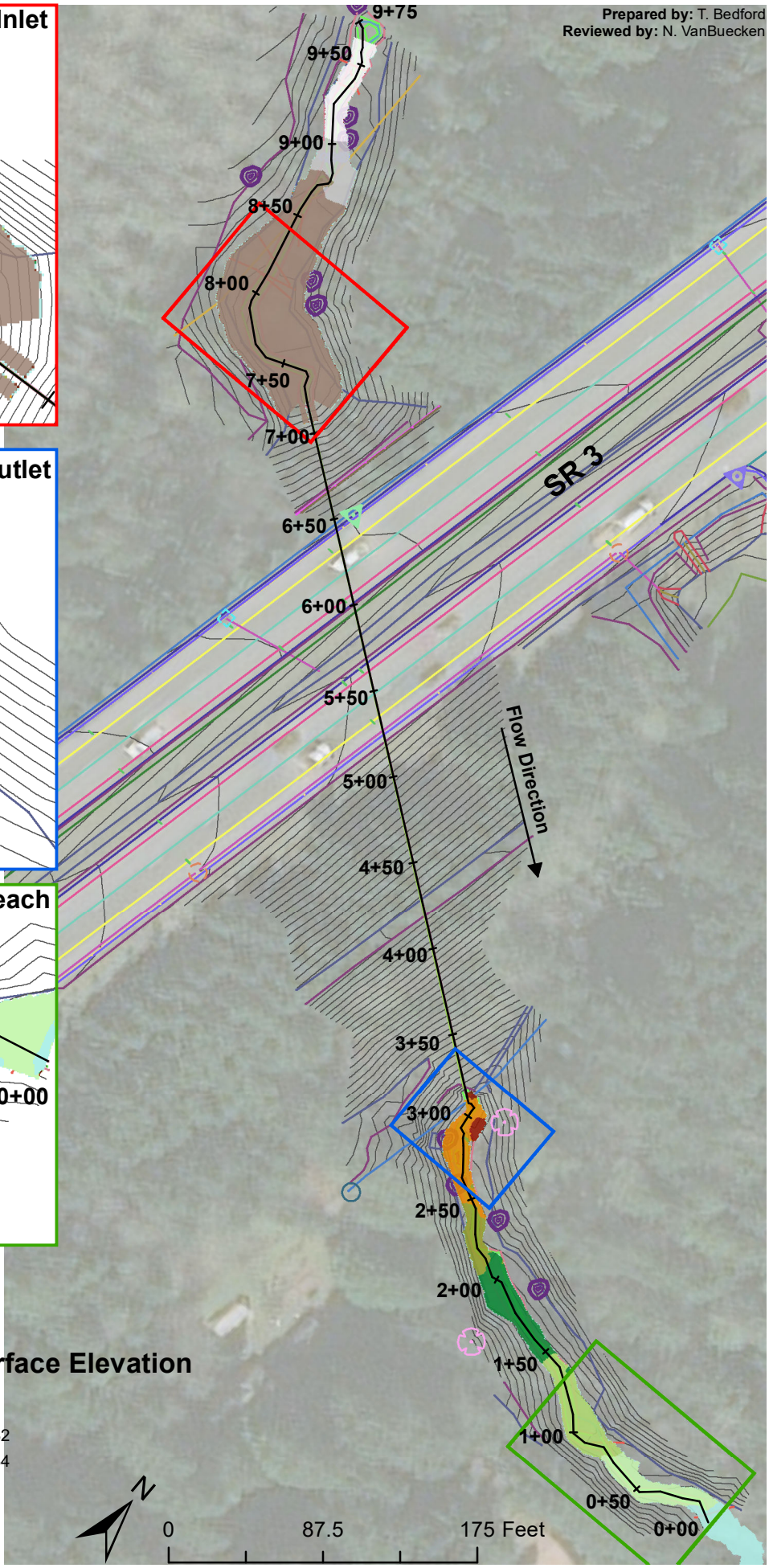








Existing Conditions, 100yr Water Surface Elevation

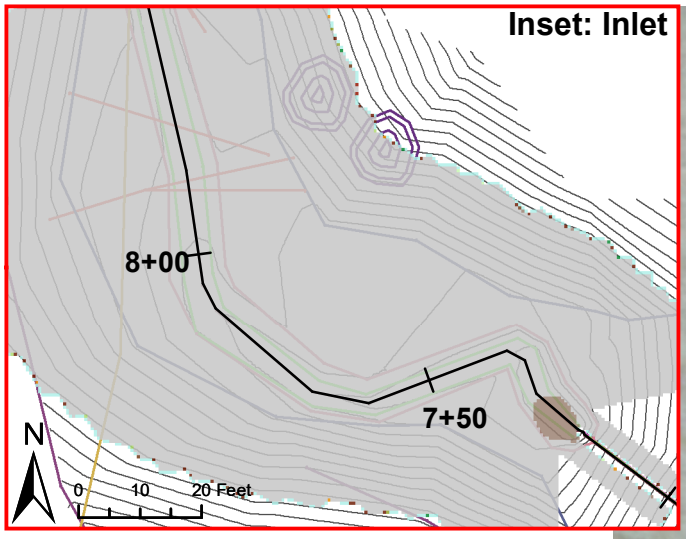
Water Surface Elevation (ft, NAVD '88)

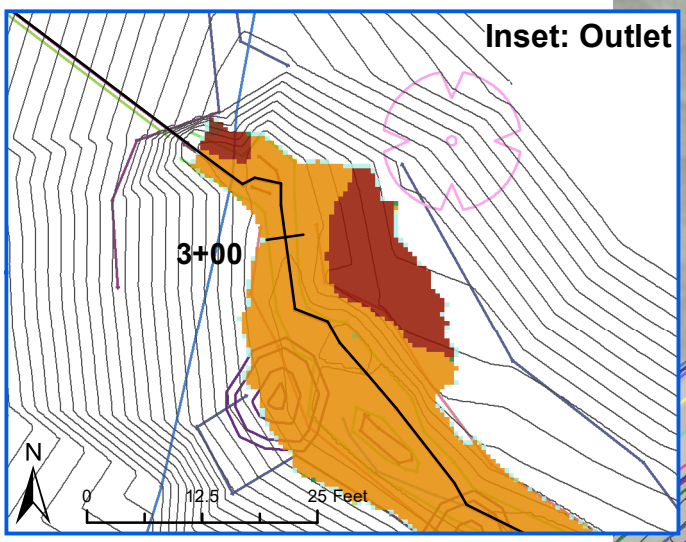
< 178	184.0 - 187	193.0 - 196	230.0 - 232
178.0 - 181	187.0 - 190	196.0 - 228	232.0 - 234
181.0 - 184	190.0 - 193	228.0 - 230	> 234

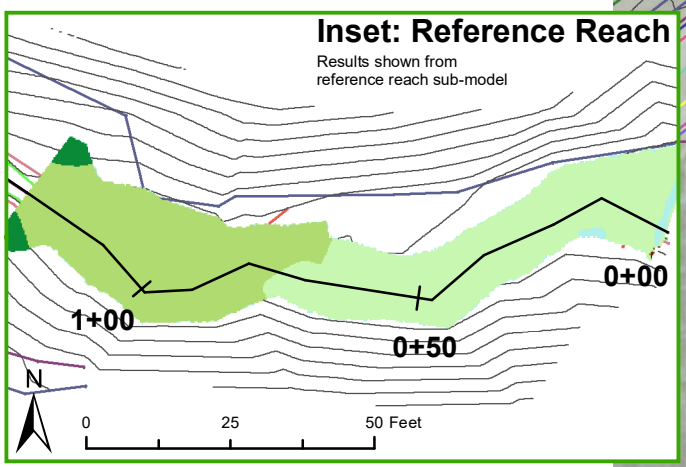
Appendix H

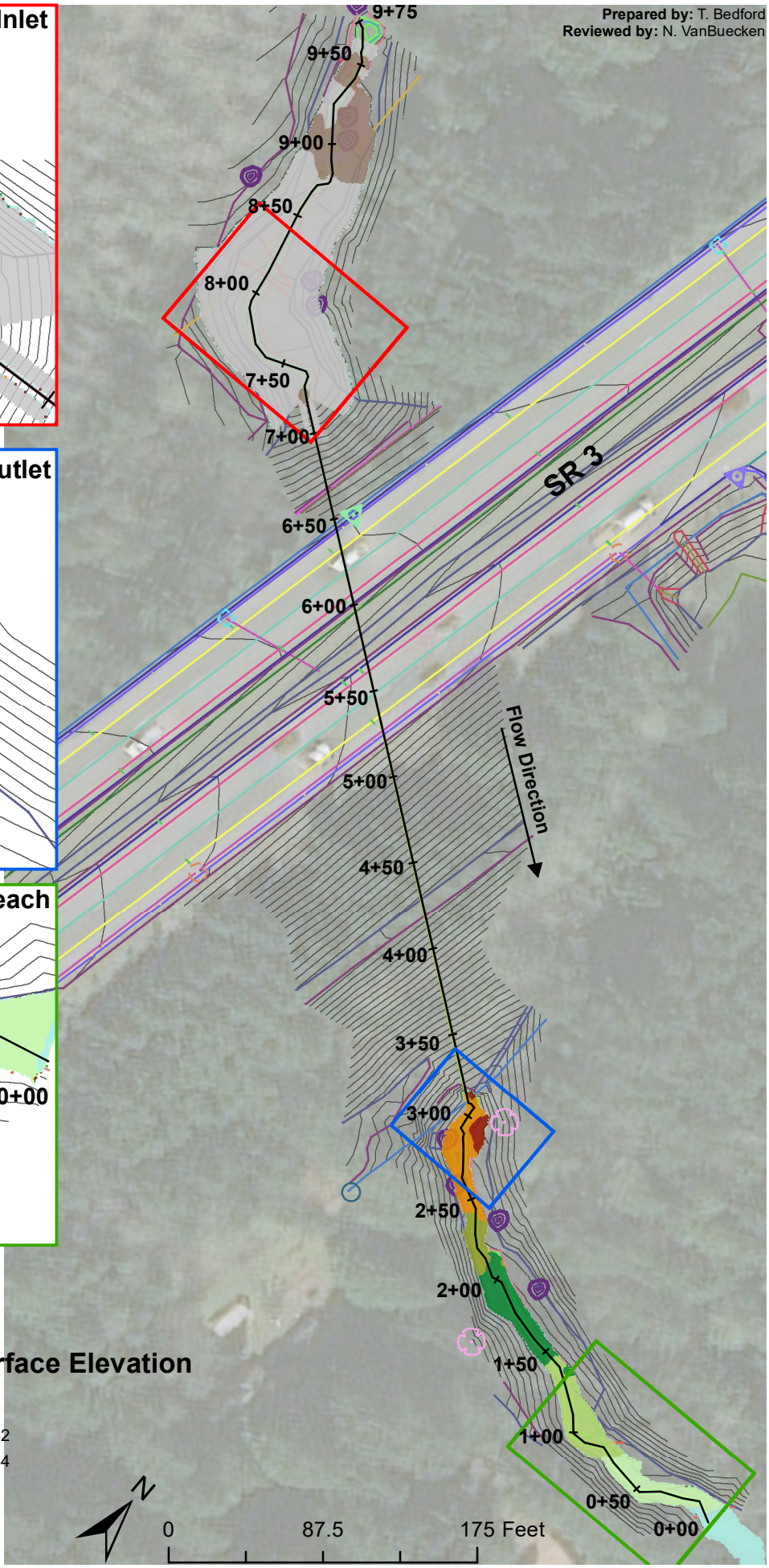
SR 3 MP 50.85 SF Johnson Creek - Model Outputs

Prepared by: T. Bedford
Reviewed by: N. VanBuecken









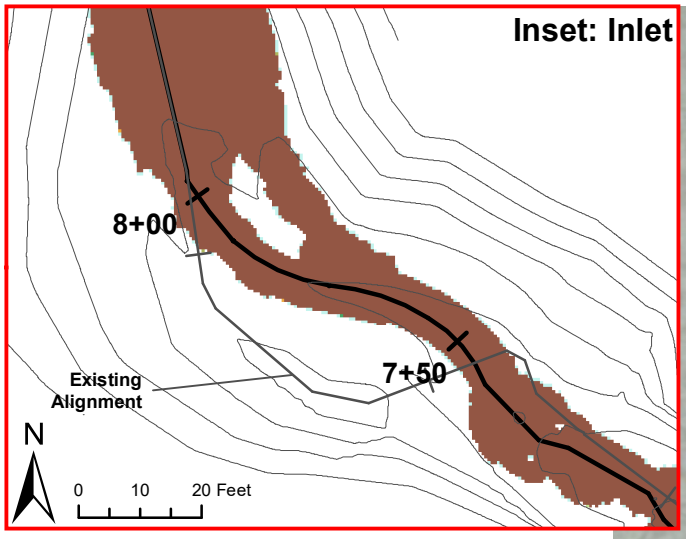
Existing Conditions, 500yr Water Surface Elevation

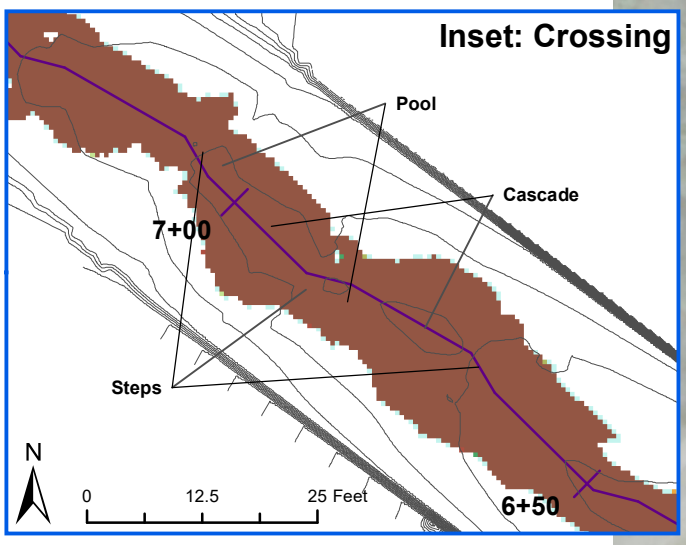
Water Surface Elevation (ft, NAVD '88)

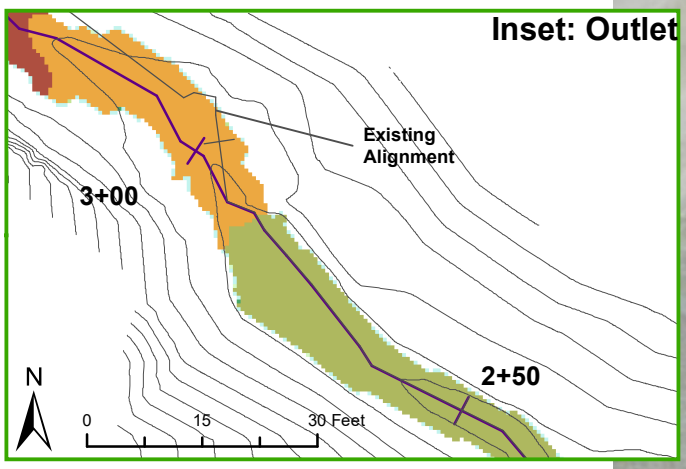
< 178	184.0 - 187	193.0 - 196	230.0 - 232
178.0 - 181	187.0 - 190	196.0 - 228	232.0 - 234
181.0 - 184	190.0 - 193	228.0 - 230	> 234

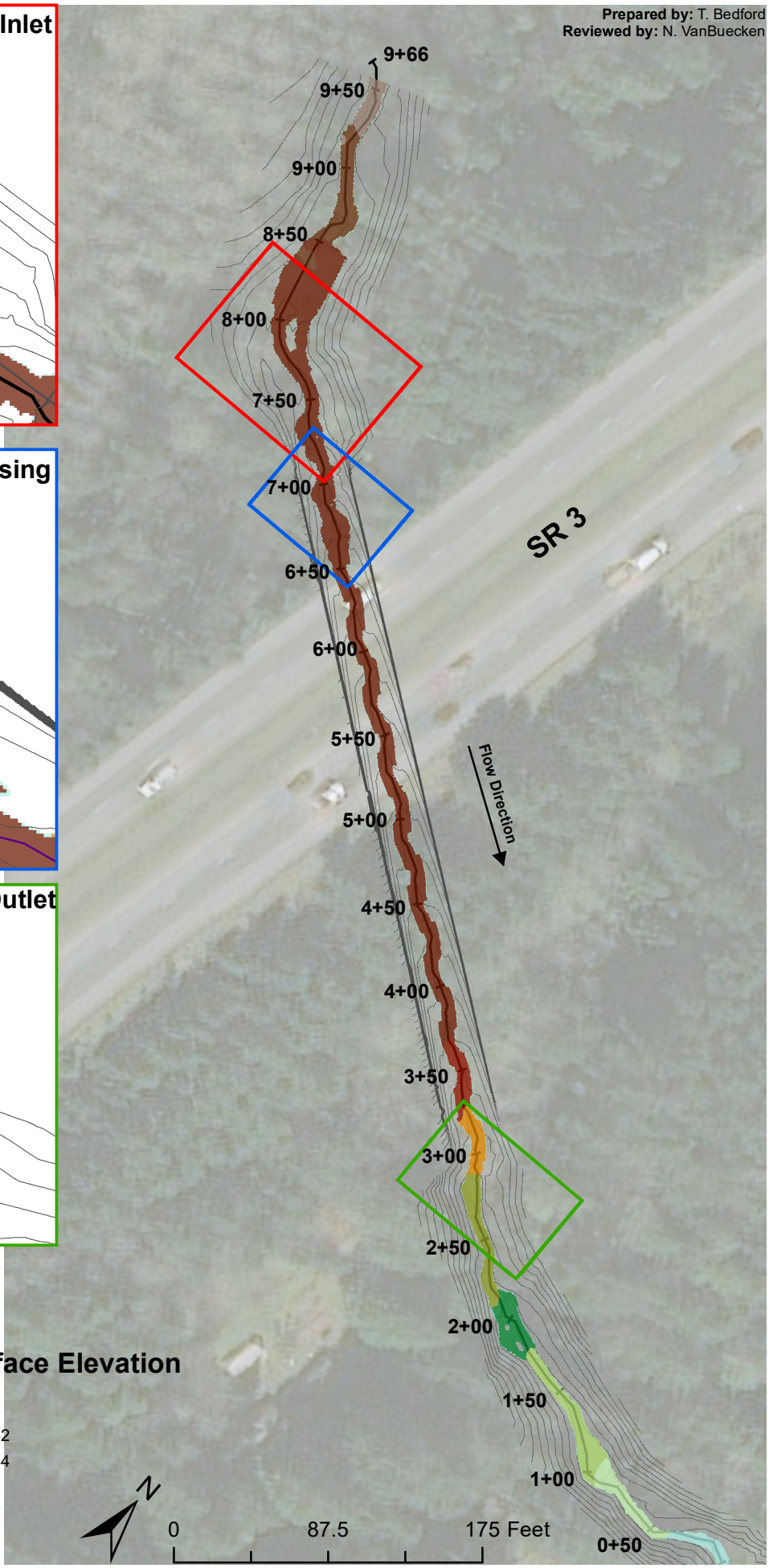
Appendix H
SR 3 MP 50.85 SF Johnson Creek - Model Outputs

Prepared by: T. Bedford
Reviewed by: N. VanBuecken









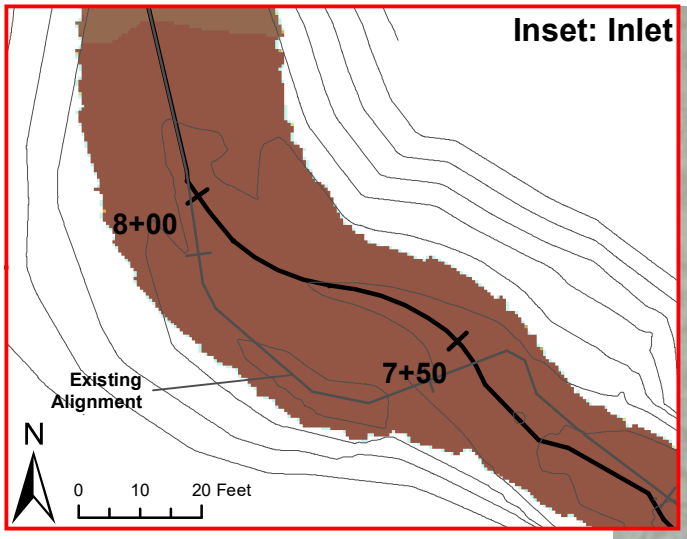
Proposed Conditions, 2yr Water Surface Elevation

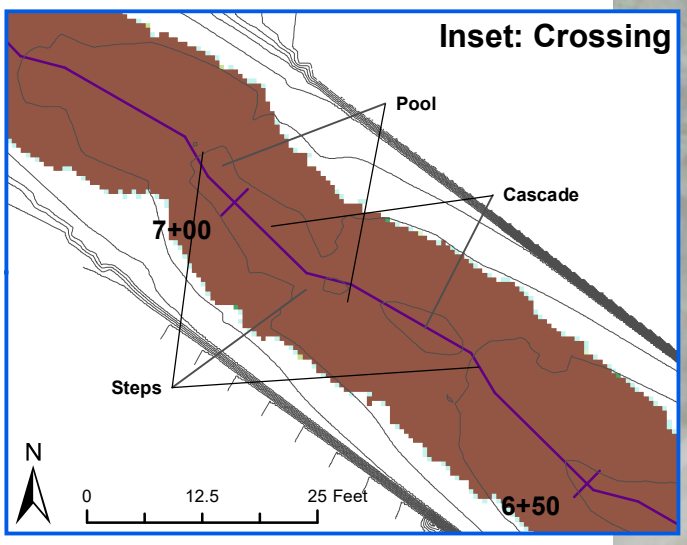
Water Surface Elevation (ft, NAVD '88)

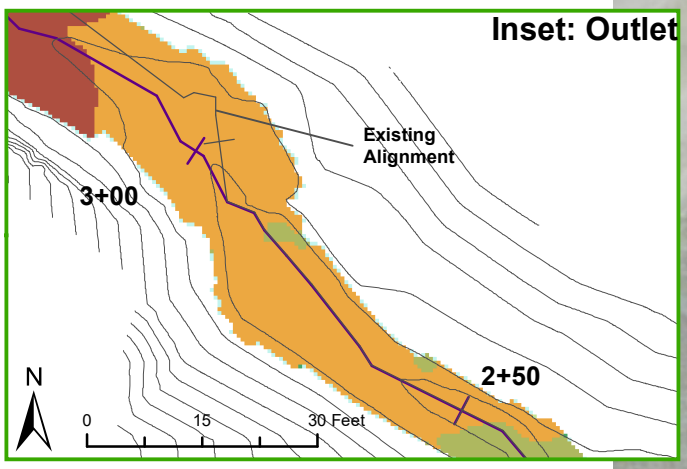
< 178	184.0 - 187	193.0 - 196	230.0 - 232
178.0 - 181	187.0 - 190	196.0 - 228	232.0 - 234
181.0 - 184	190.0 - 193	228.0 - 230	> 234

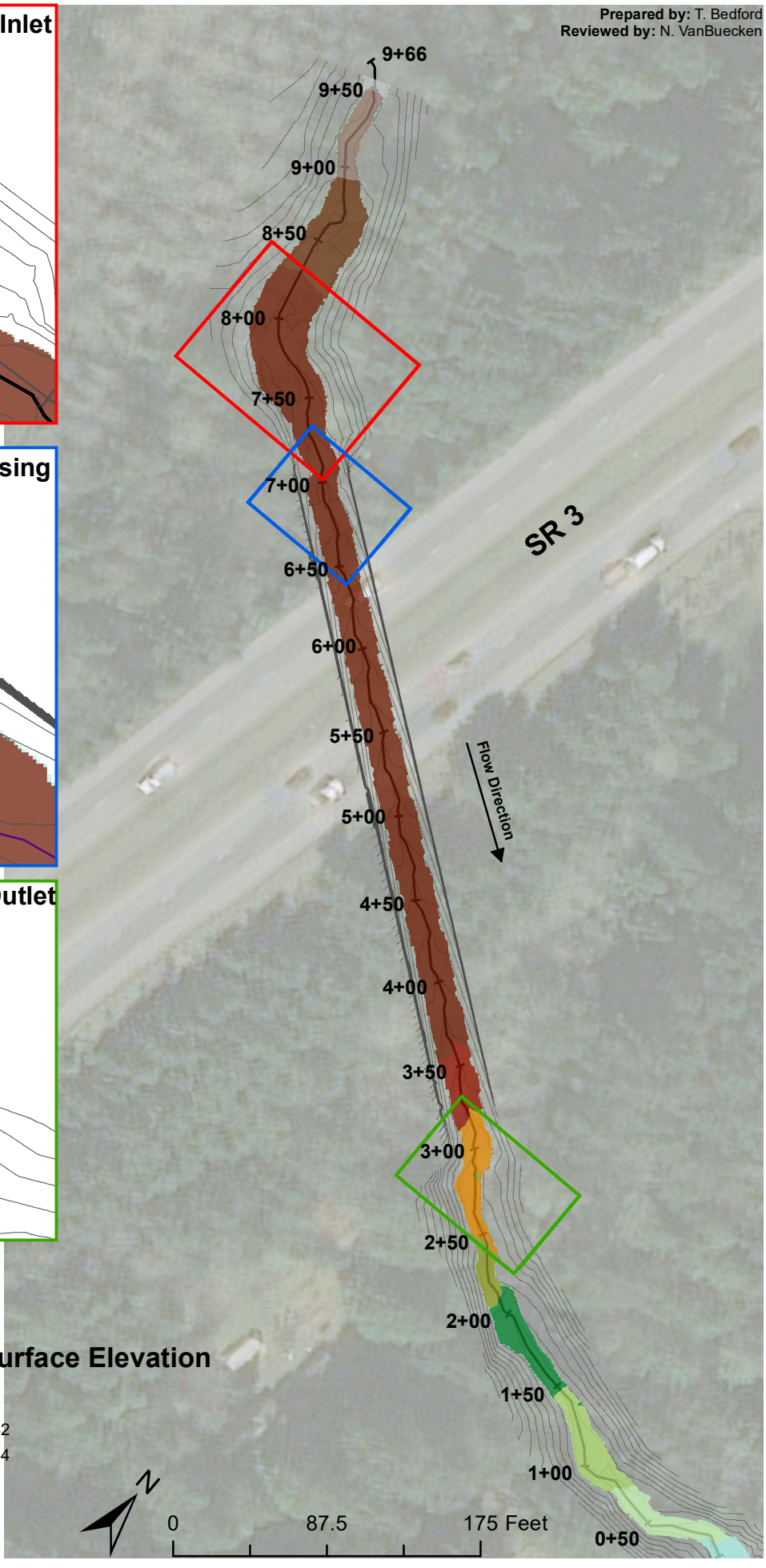
Appendix H
SR 3 MP 50.85 SF Johnson Creek - Model Outputs

Prepared by: T. Bedford
Reviewed by: N. VanBuecken









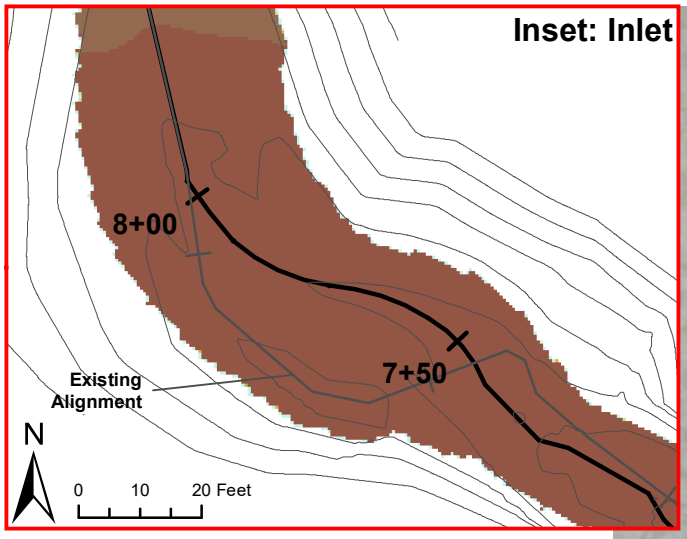
Proposed Conditions, 100yr Water Surface Elevation

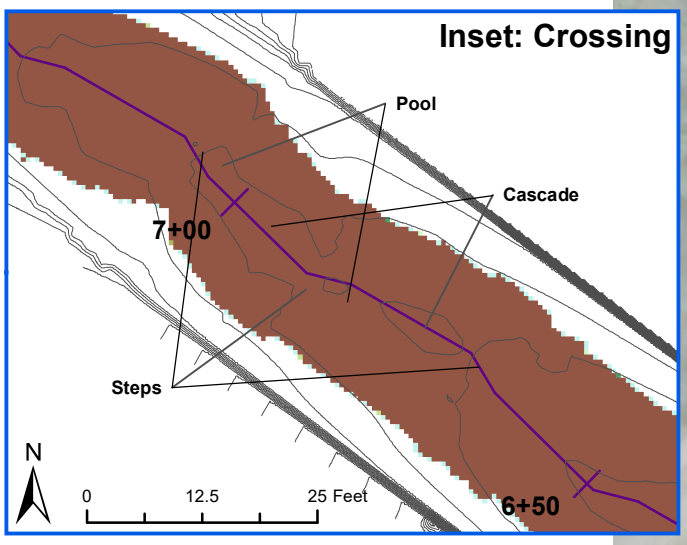
Water Surface Elevation (ft, NAVD '88)

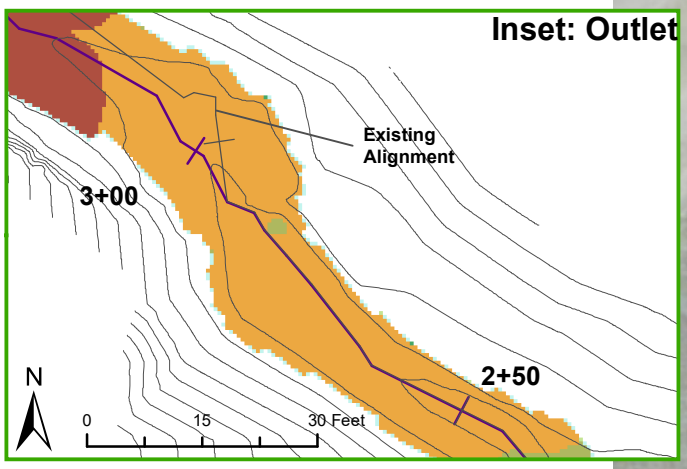
< 178	184.0 - 187	193.0 - 196	230.0 - 232
178.0 - 181	187.0 - 190	196.0 - 228	232.0 - 234
181.0 - 184	190.0 - 193	228.0 - 230	> 234

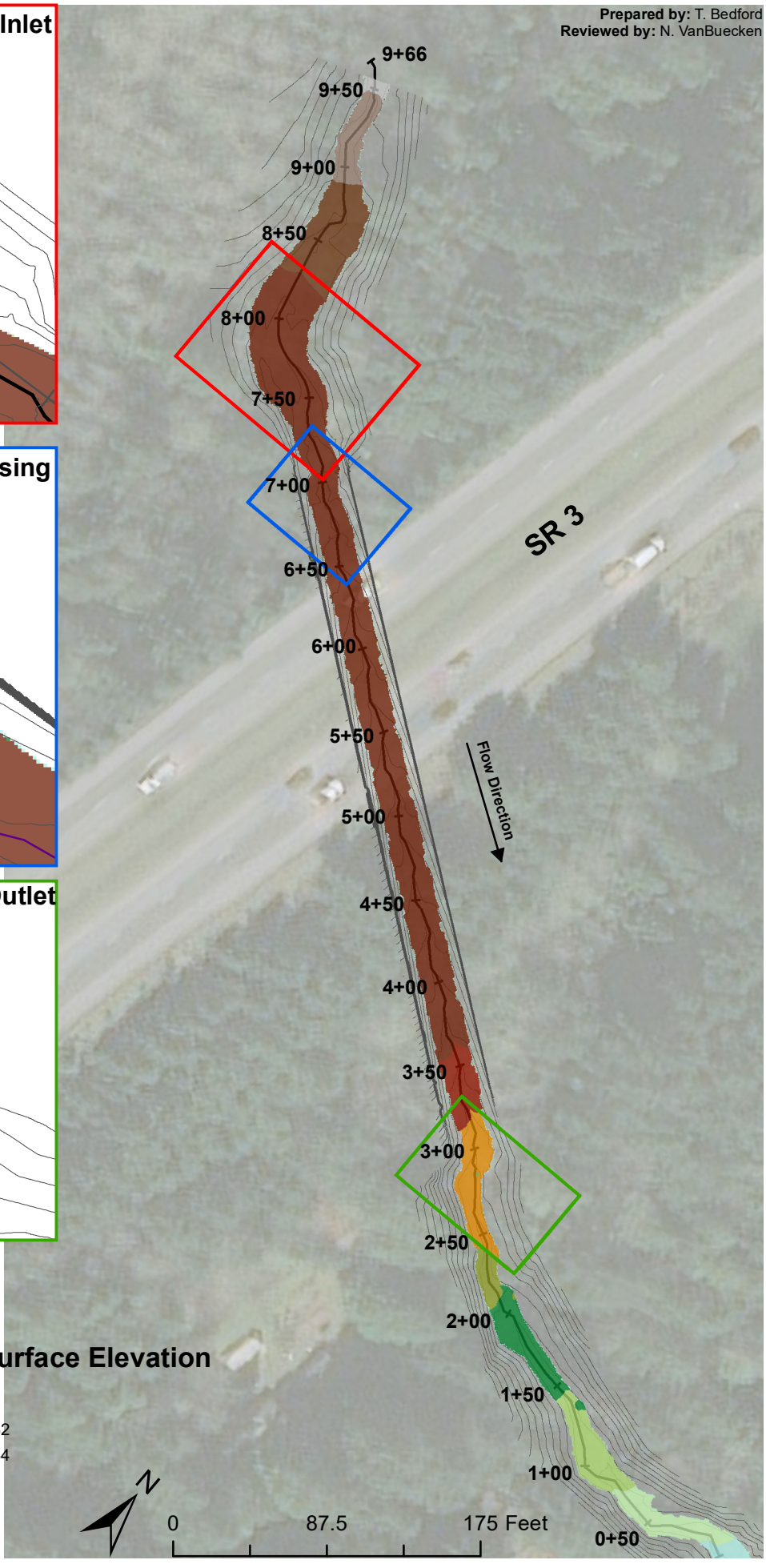
Appendix H
SR 3 MP 50.85 SF Johnson Creek - Model Outputs

Prepared by: T. Bedford
Reviewed by: N. VanBuecken









Proposed Conditions, 500yr Water Surface Elevation

Water Surface Elevation (ft, NAVD '88)

< 178	184.0 - 187	193.0 - 196	230.0 - 232
178.0 - 181	187.0 - 190	196.0 - 228	232.0 - 234
181.0 - 184	190.0 - 193	228.0 - 230	> 234

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SR 3 MP 50.85 SF Johnson Creek - Model Outputs

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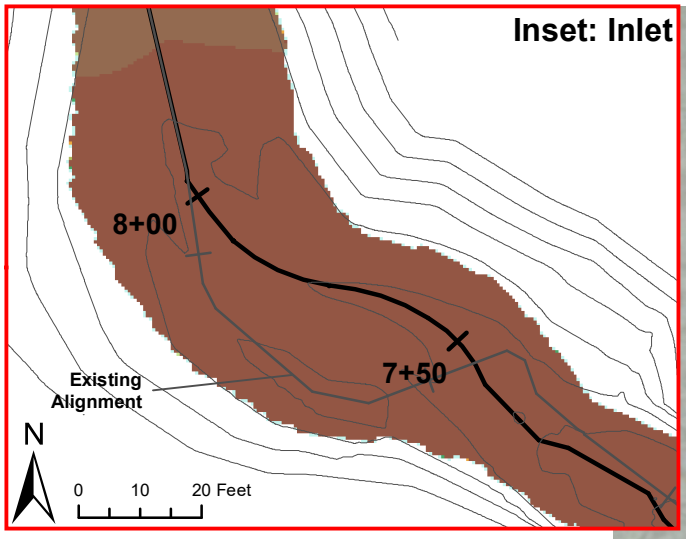
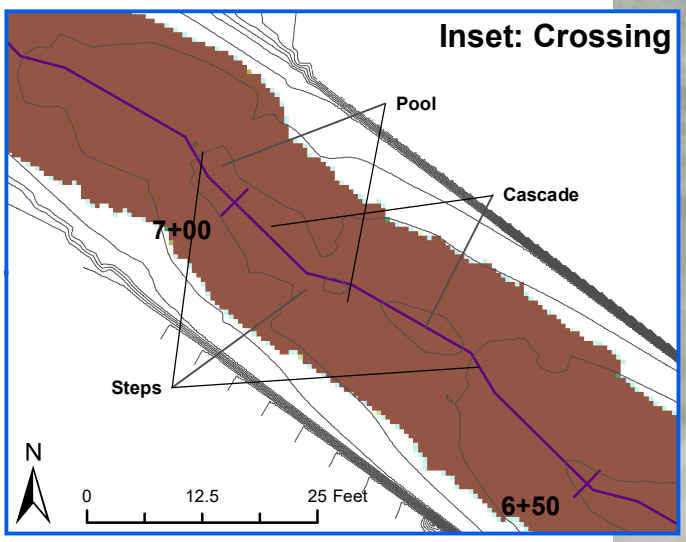
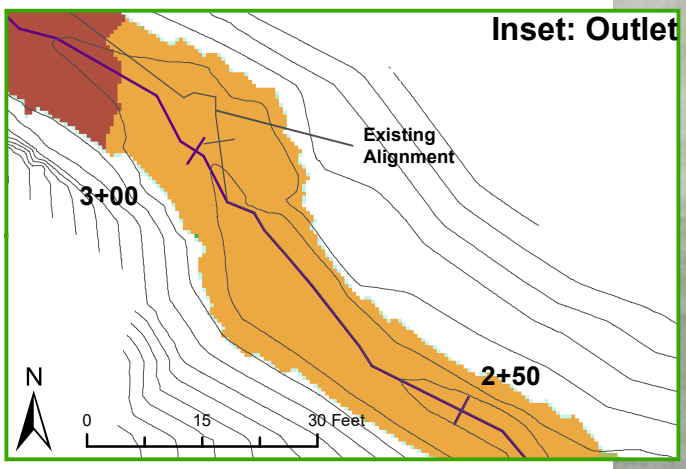
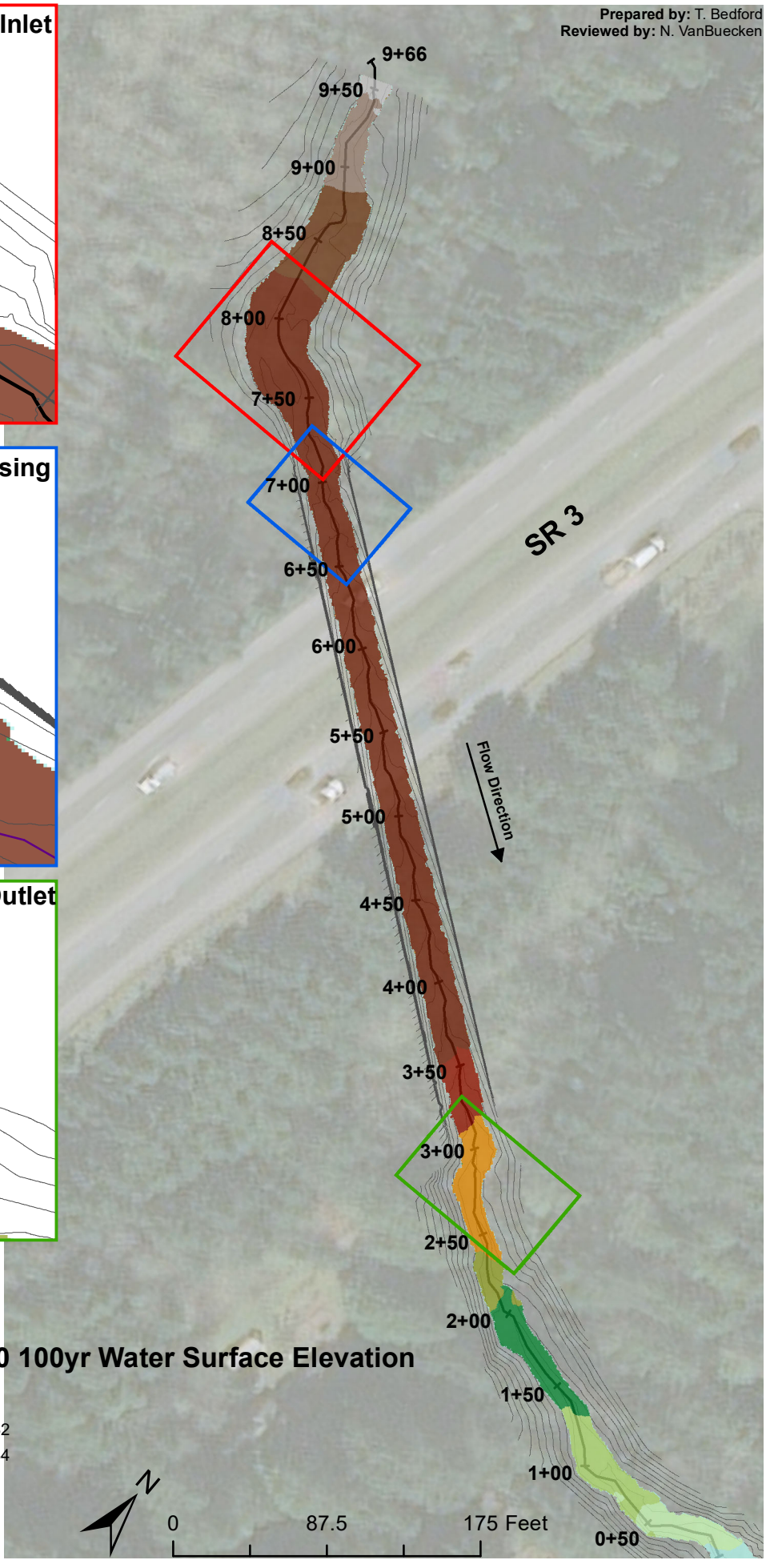
Reviewed by: N. VanBuecken









Proposed Conditions, Projected 2080 100yr Water Surface Elevation

Water Surface Elevation (ft, NAVD '88)

< 178	184.0 - 187	193.0 - 196	230.0 - 232
178.0 - 181	187.0 - 190	196.0 - 228	232.0 - 234
181.0 - 184	190.0 - 193	228.0 - 230	> 234

Appendix H

SR 3 MP 50.85 SF Johnson Creek - Model Outputs

Prepared by: T. Bedford
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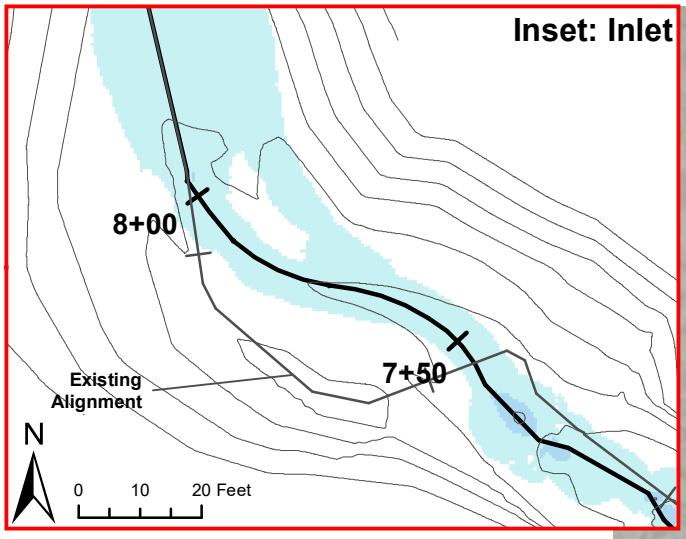
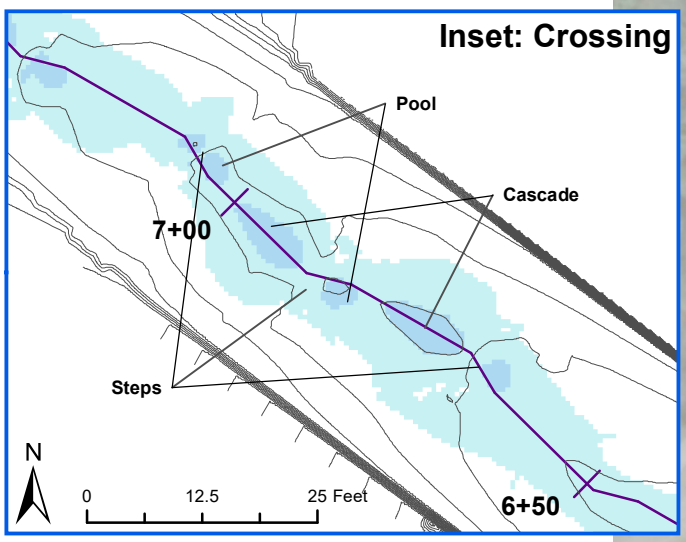
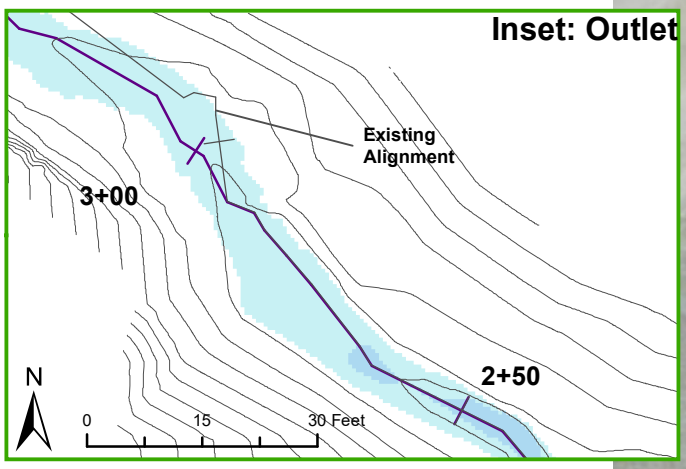
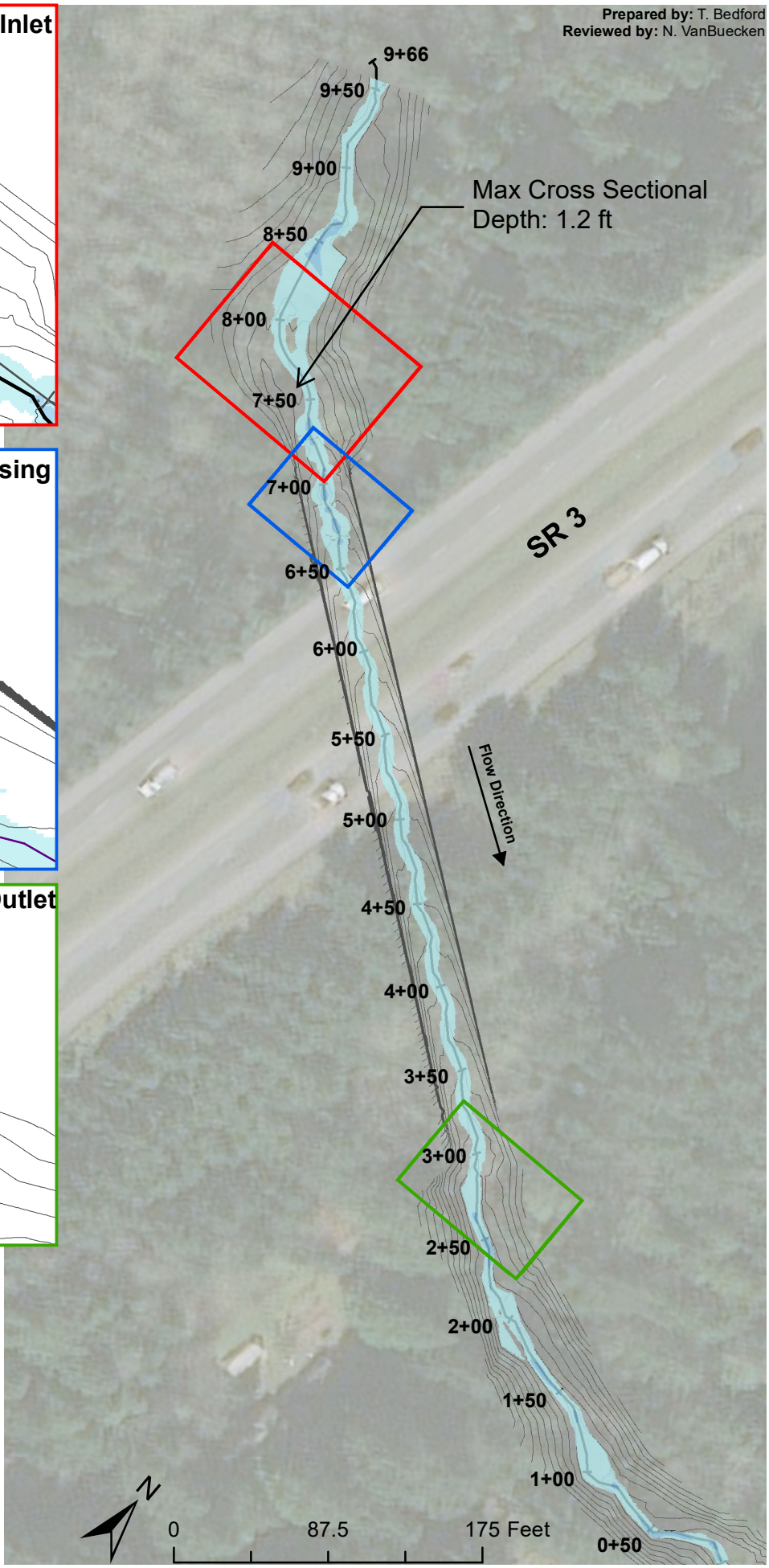








Proposed Conditions, 2yr Depth

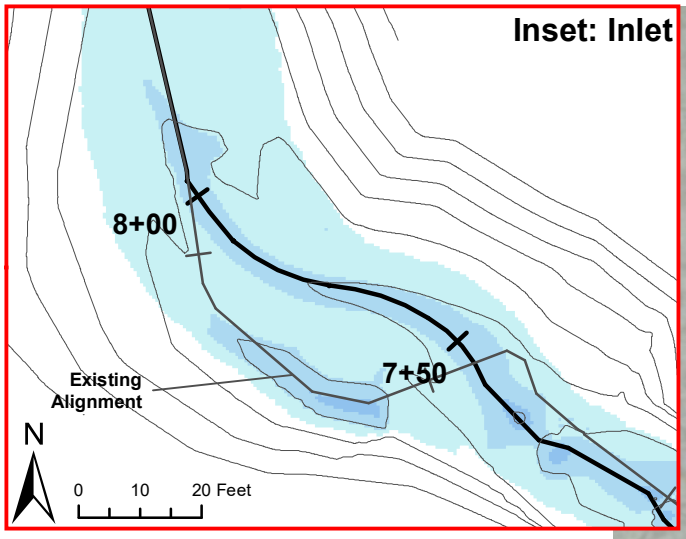
Depth (ft)

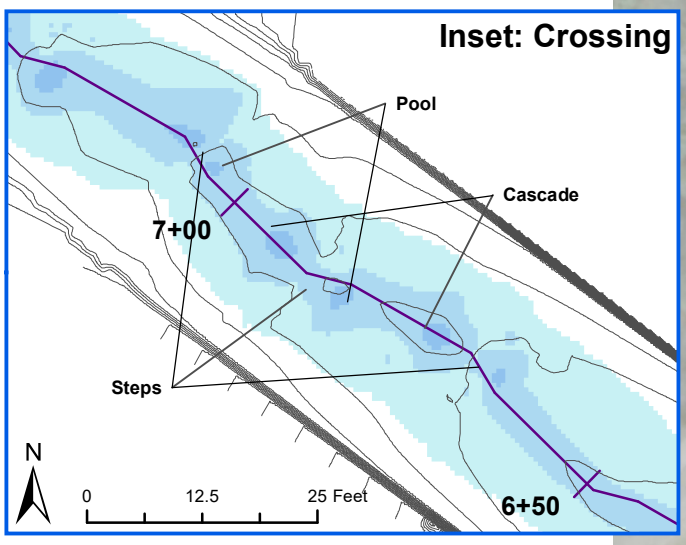
- < 1
- 1.0 - 2
- 2.0 - 3
- 3.0 - 4
- 4.0 - 5
- 5.0 - 10
- 10.0 - 15
- > 15.0

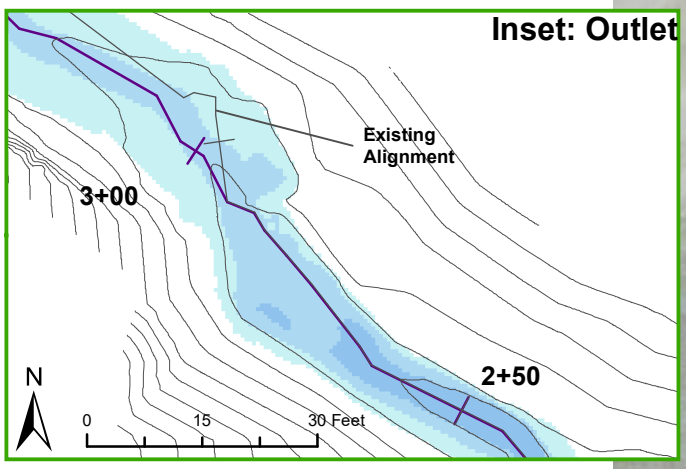
Appendix H

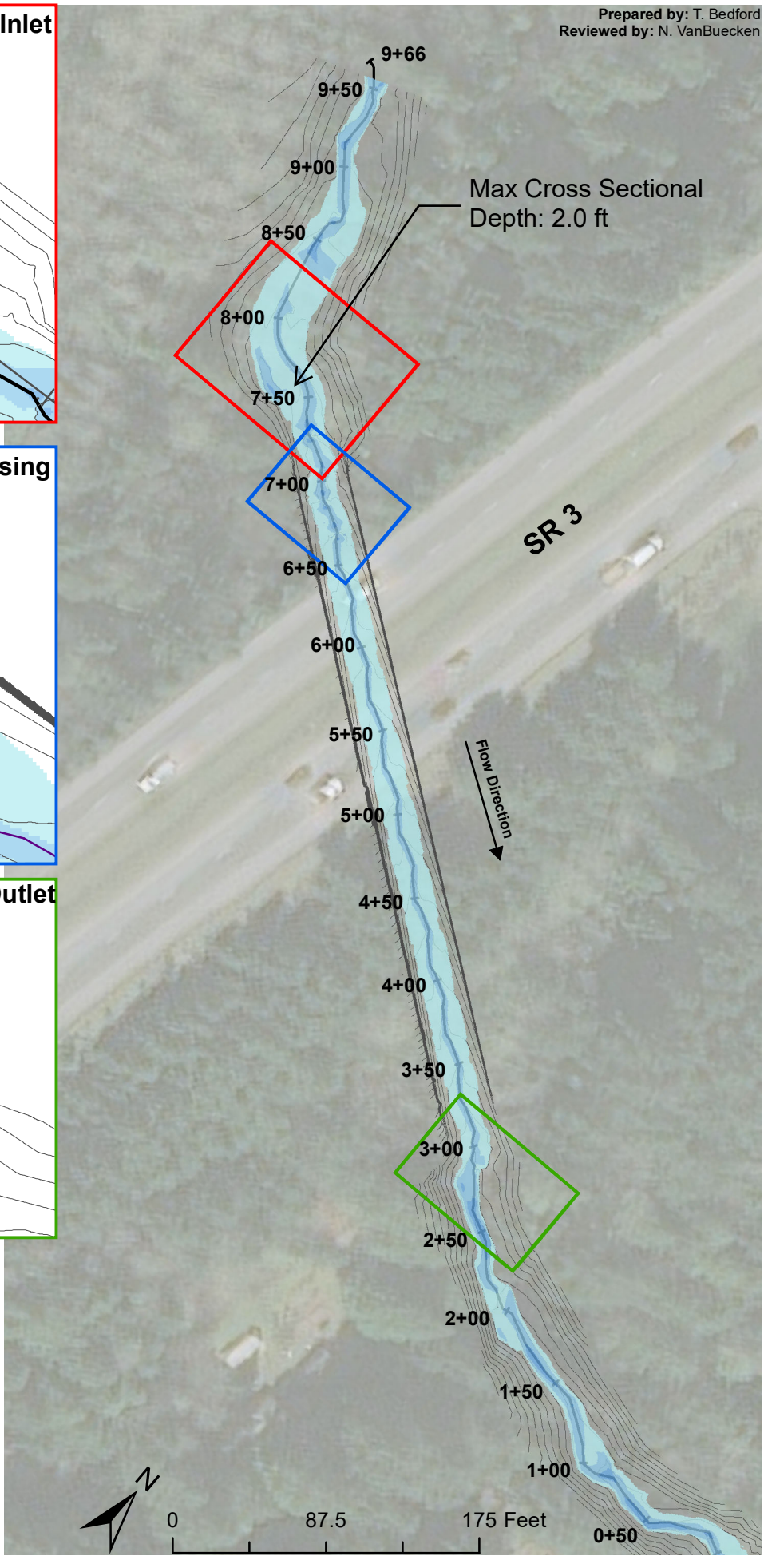
SR 3 MP 50.85 SF Johnson Creek - Model Outputs

Prepared by: T. Bedford
Reviewed by: N. VanBuecken









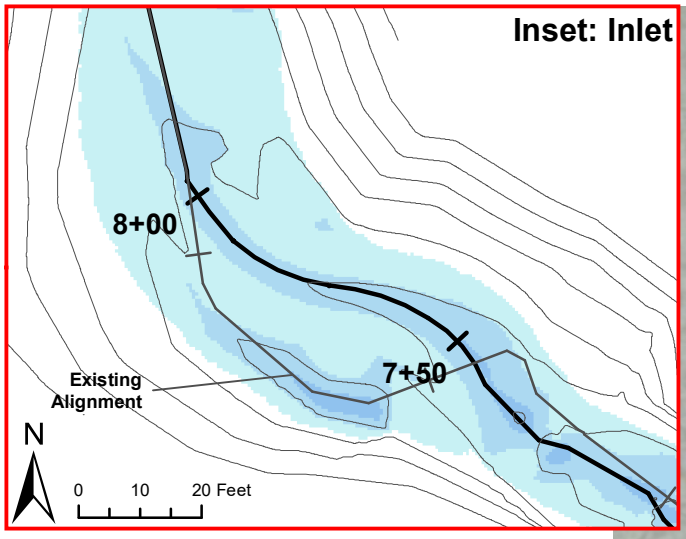
Proposed Conditions, 100yr Depth

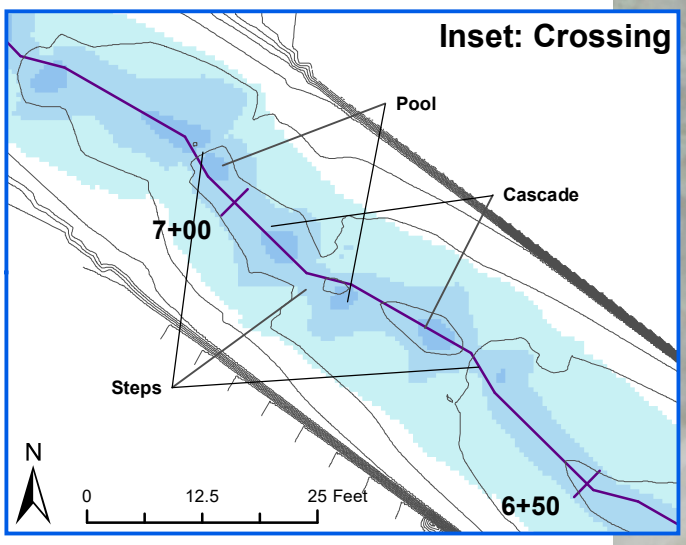
Depth (ft)

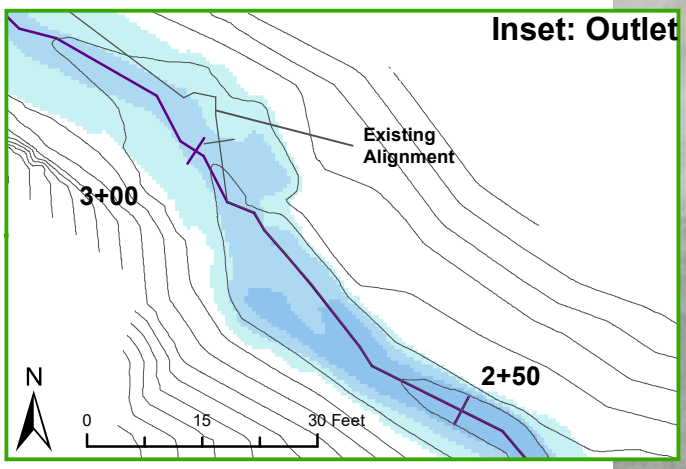
- < 1
- 1.0 - 2
- 2.0 - 3
- 3.0 - 4
- 4.0 - 5
- 5.0 - 10
- 10.0 - 15
- > 15.0

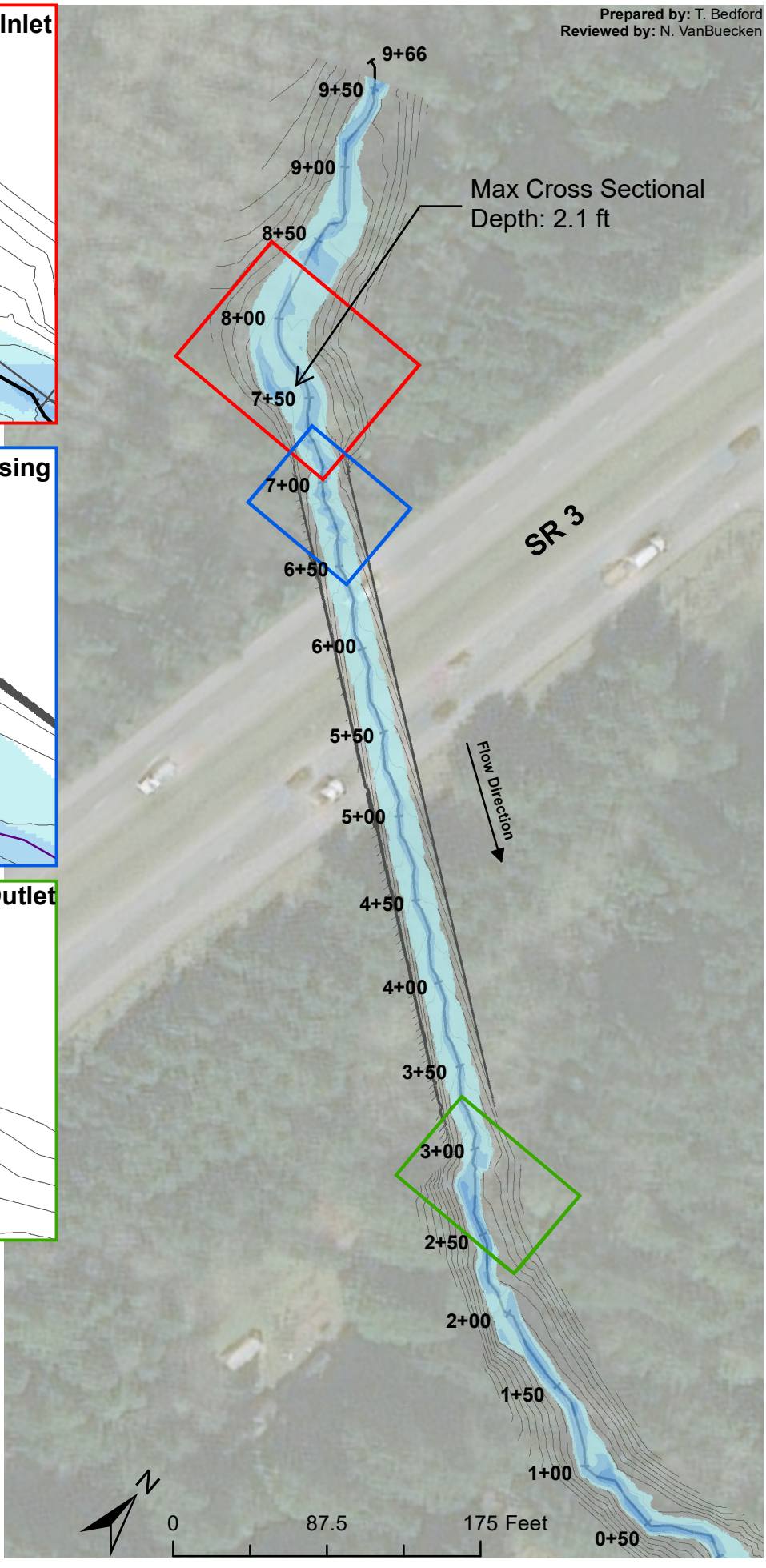
Appendix H

SR 3 MP 50.85 SF Johnson Creek - Model Outputs









Proposed Conditions, 500yr Depth

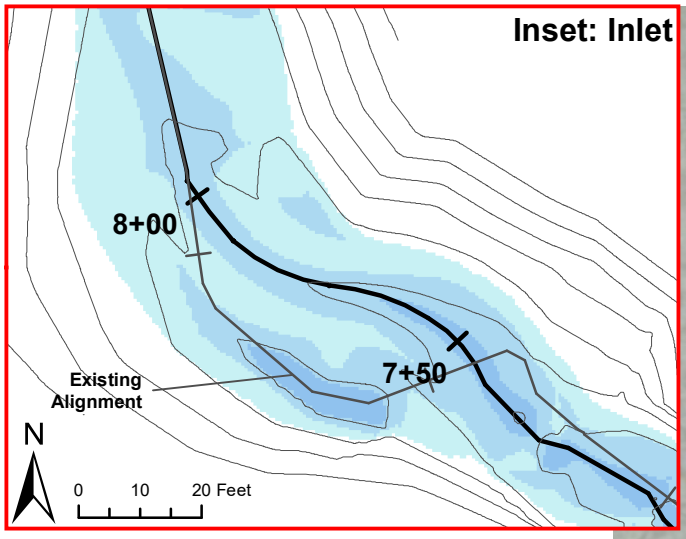
Depth (ft)

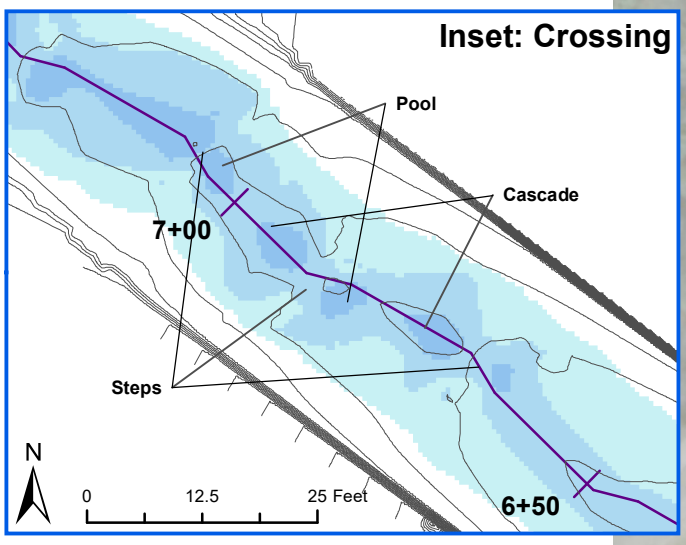
- < 1
- 1.0 - 2
- 2.0 - 3
- 3.0 - 4
- 4.0 - 5
- 5.0 - 10
- 10.0 - 15
- > 15.0

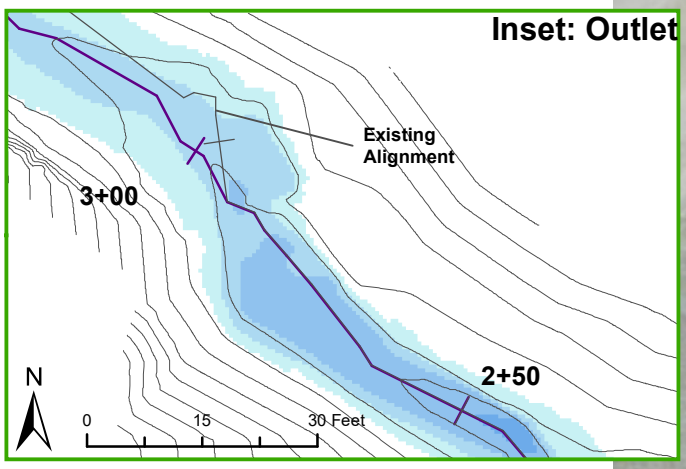
Appendix H

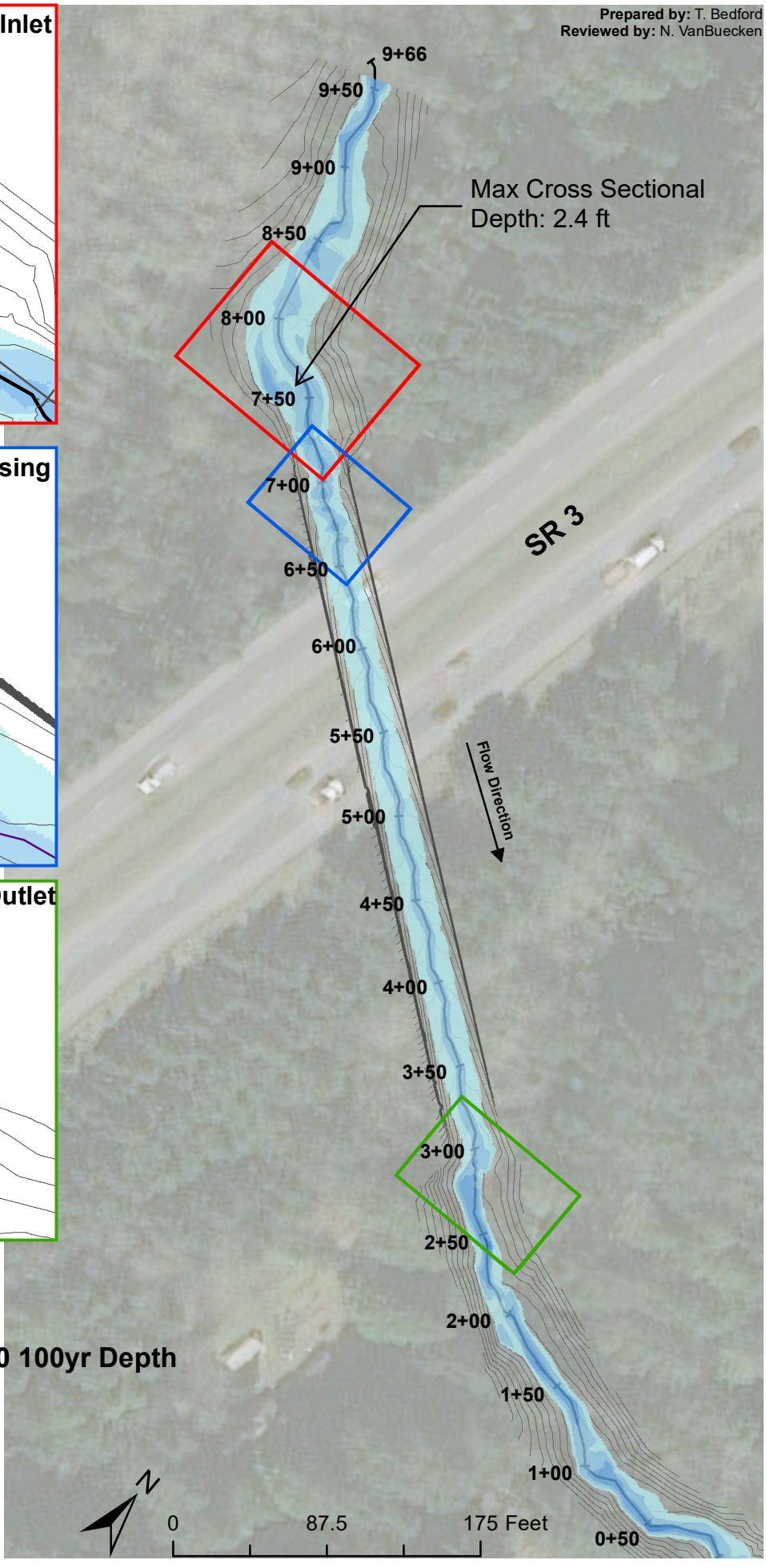
SR 3 MP 50.85 SF Johnson Creek - Model Outputs

Prepared by: T. Bedford
Reviewed by: N. VanBuecken









Proposed Conditions, Projected 2080 100yr Depth

Depth (ft)

- < 1
- 1.0 - 2
- 2.0 - 3
- 3.0 - 4
- 4.0 - 5
- 5.0 - 10
- 10.0 - 15
- > 15.0

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SR 3 MP 50.85 SF Johnson Creek - Model Outputs

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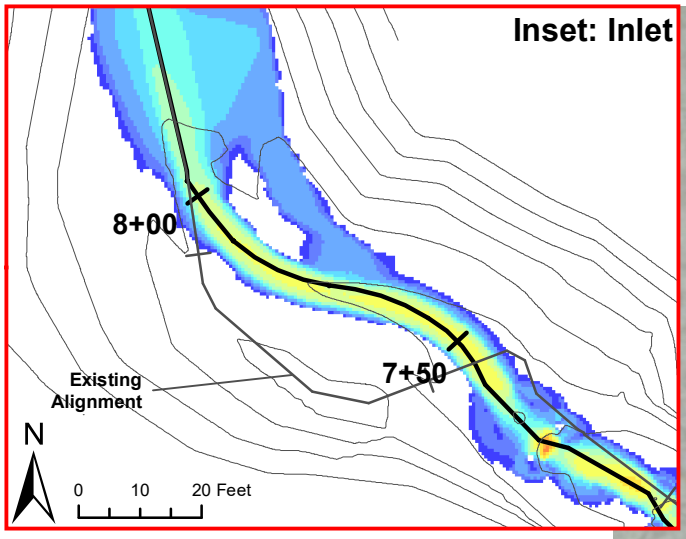
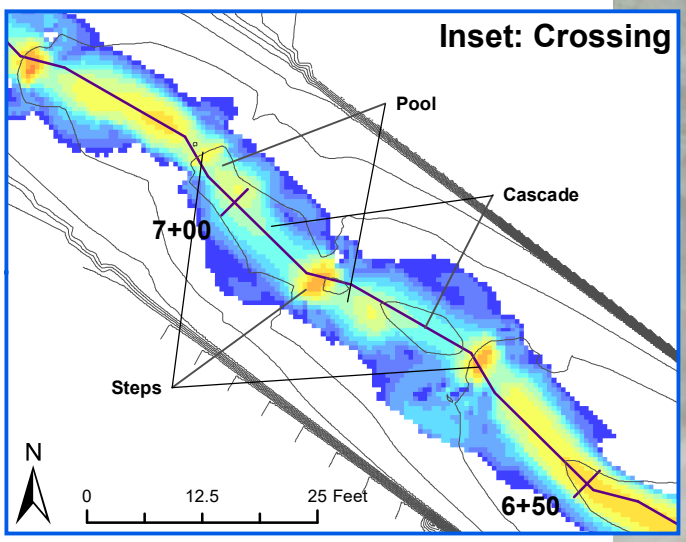
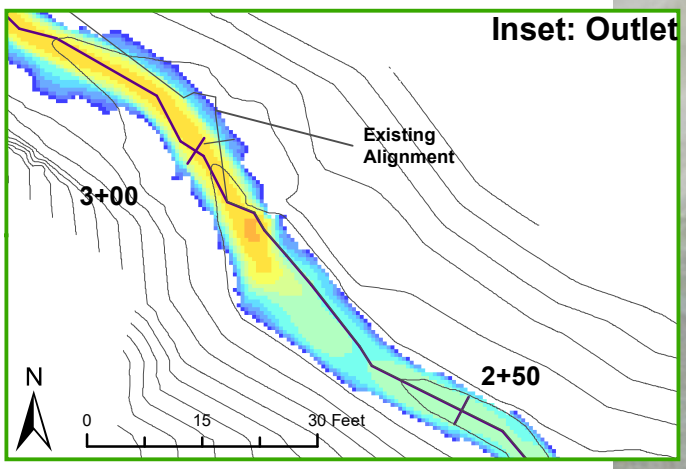
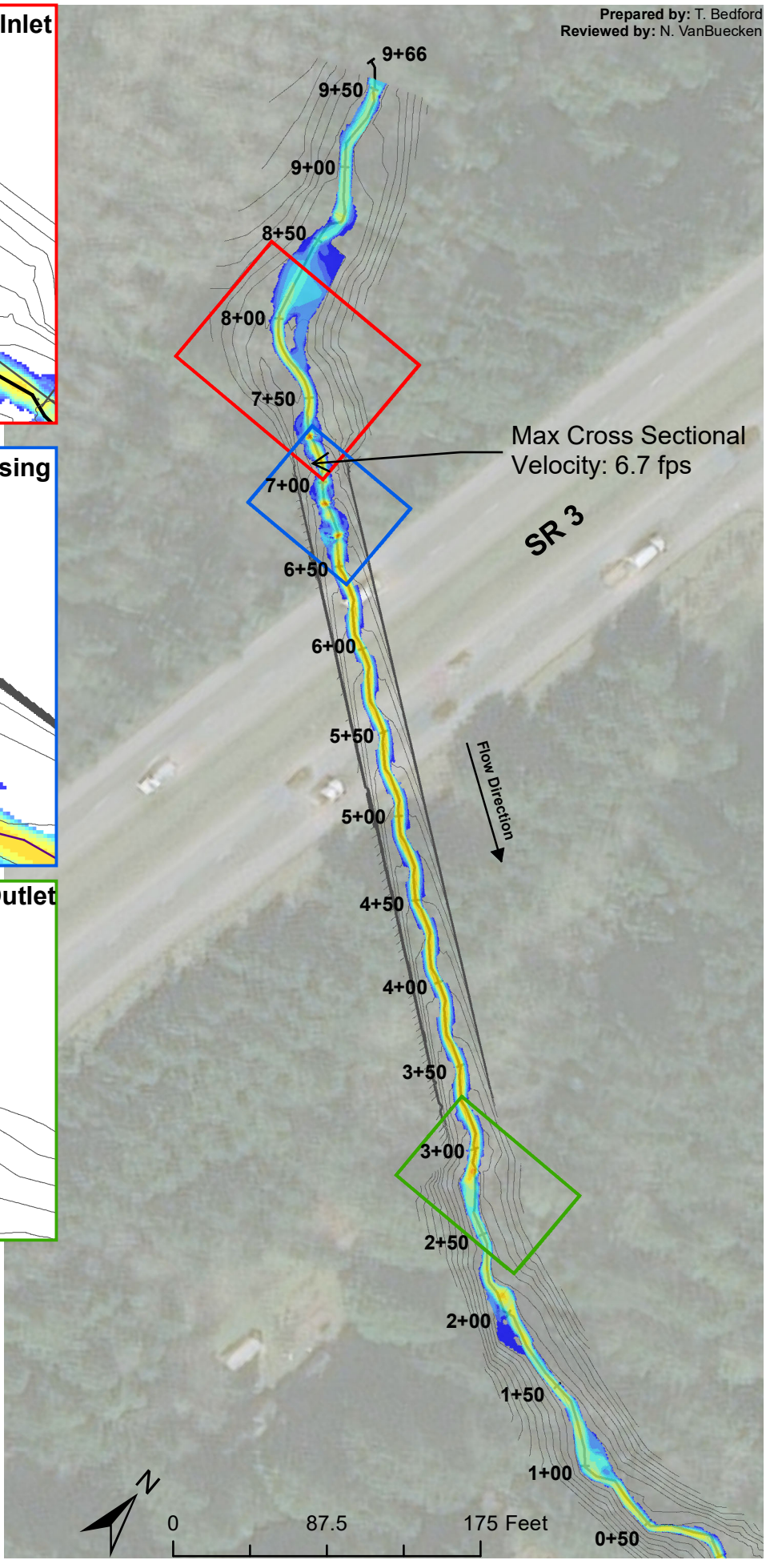
Reviewed by: N. VanBuecken









Proposed Conditions, 2yr Velocity

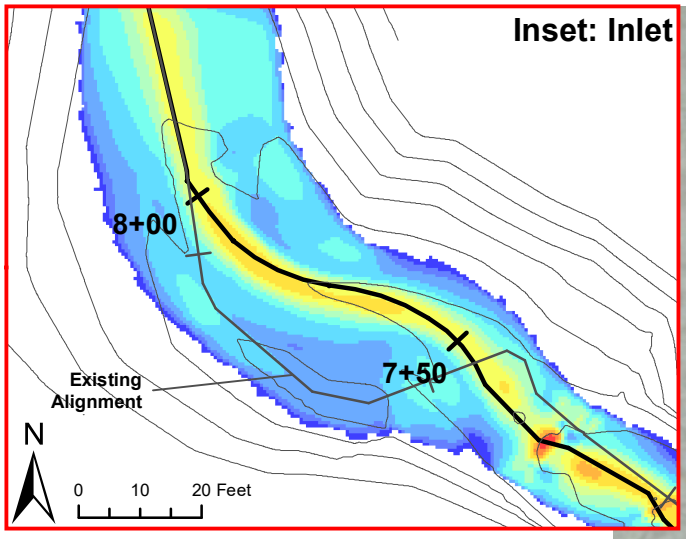
Velocity (fps)

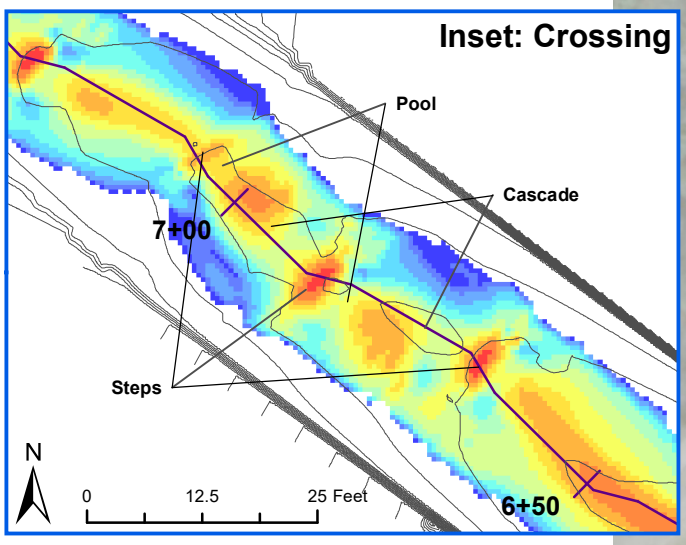
< 0.25	2.0 - 3	6.0 - 7
0.25 - 0.5	3.0 - 4	7.0 - 8
0.5 - 1	4.0 - 5	8.0 - 9
1.0 - 2	5.0 - 6	

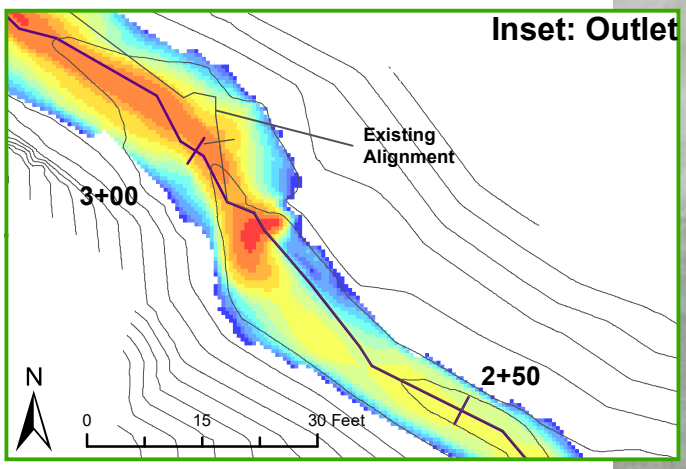
Appendix H

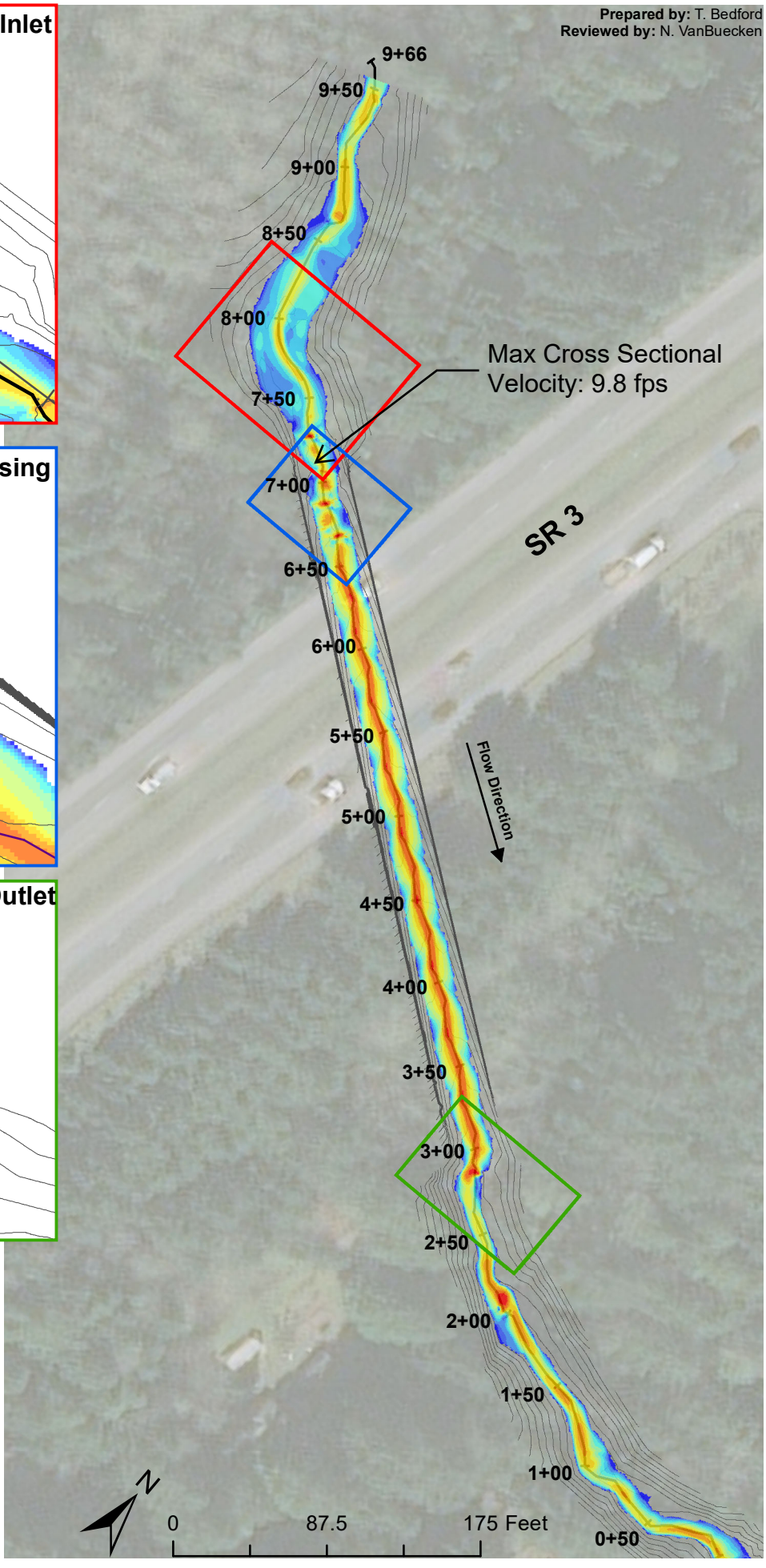
SR 3 MP 50.85 SF Johnson Creek - Model Outputs

Prepared by: T. Bedford
Reviewed by: N. VanBuecken









Proposed Conditions, 100yr Velocity

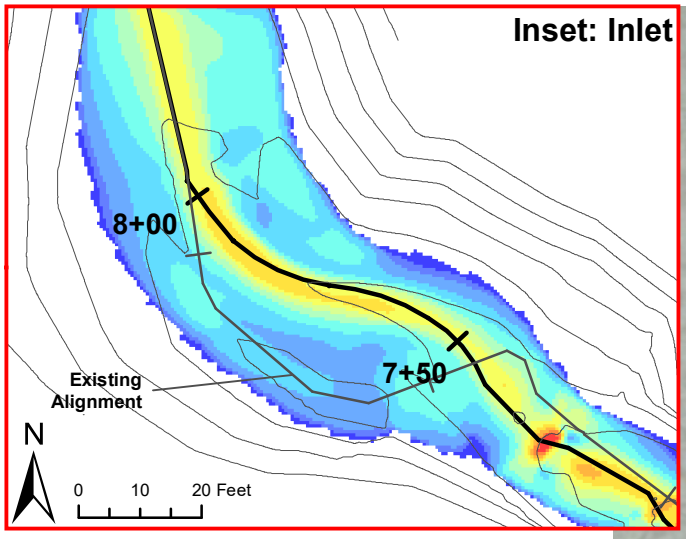
Velocity (fps)

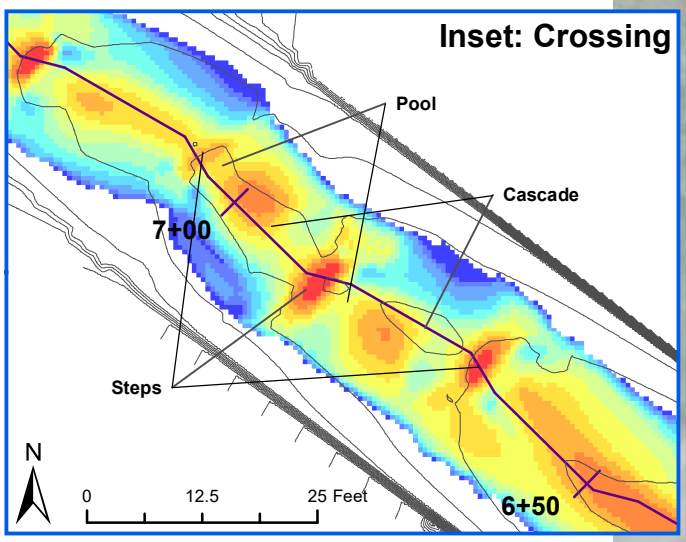
< 0.25	2.0 - 3	6.0 - 7
0.25 - 0.5	3.0 - 4	7.0 - 8
0.5 - 1	4.0 - 5	8.0 - 9
1.0 - 2	5.0 - 6	

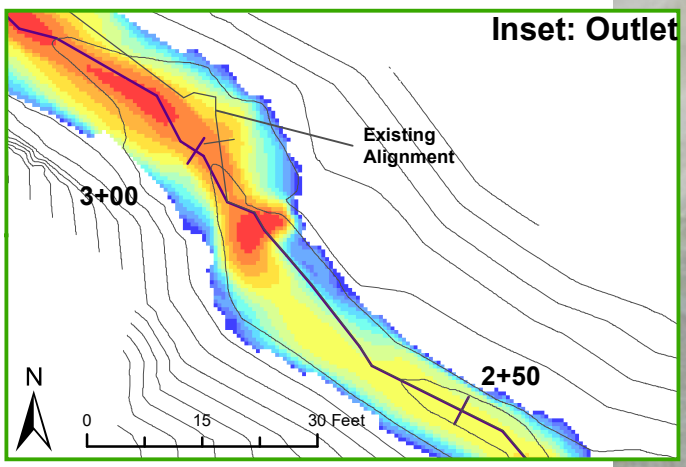
Appendix H

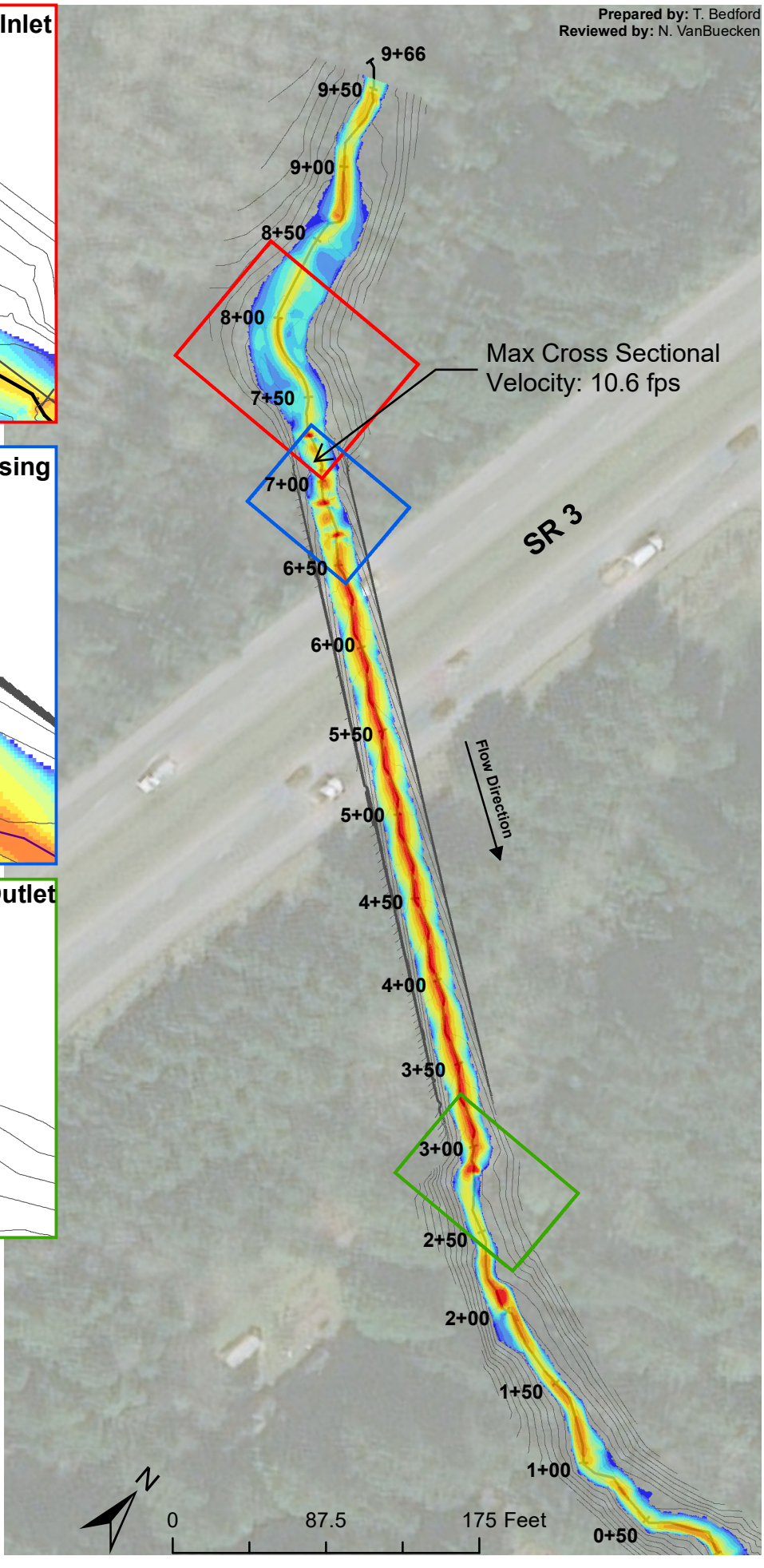
SR 3 MP 50.85 SF Johnson Creek - Model Outputs

Prepared by: T. Bedford
Reviewed by: N. VanBuecken









Proposed Conditions, 500yr Velocity

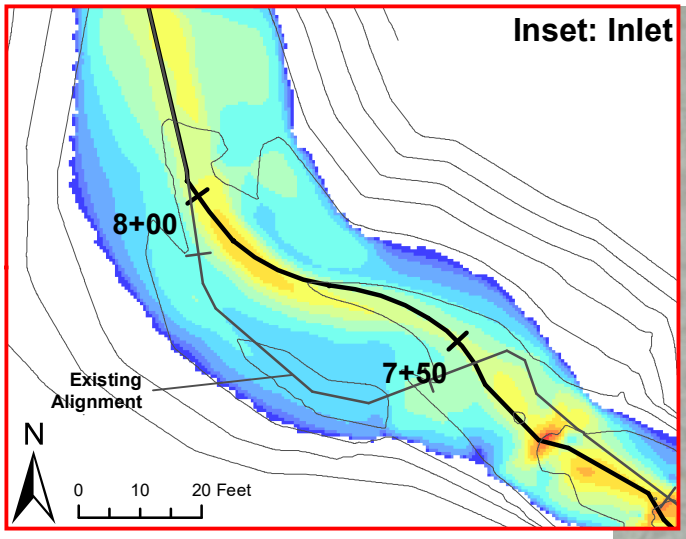
Velocity (fps)

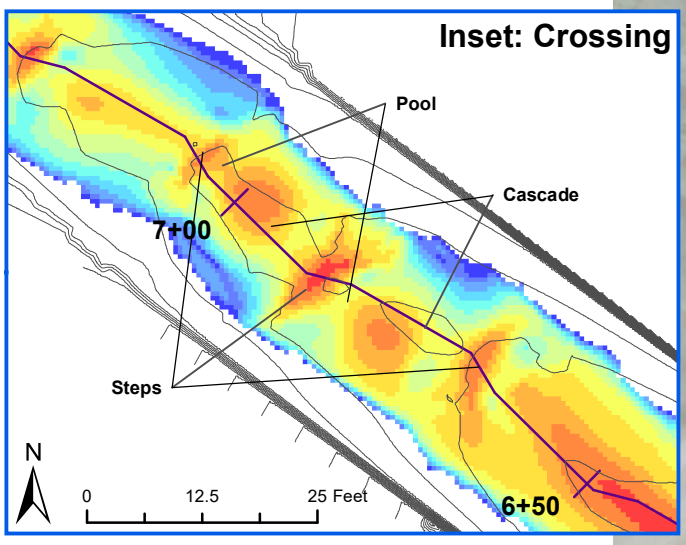
< 0.25	2.0 - 3	6.0 - 7
0.25 - 0.5	3.0 - 4	7.0 - 8
0.5 - 1	4.0 - 5	8.0 - 9
1.0 - 2	5.0 - 6	

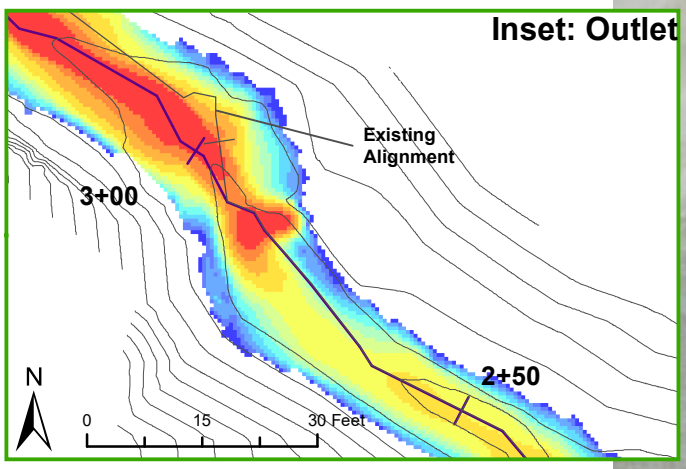
Appendix H

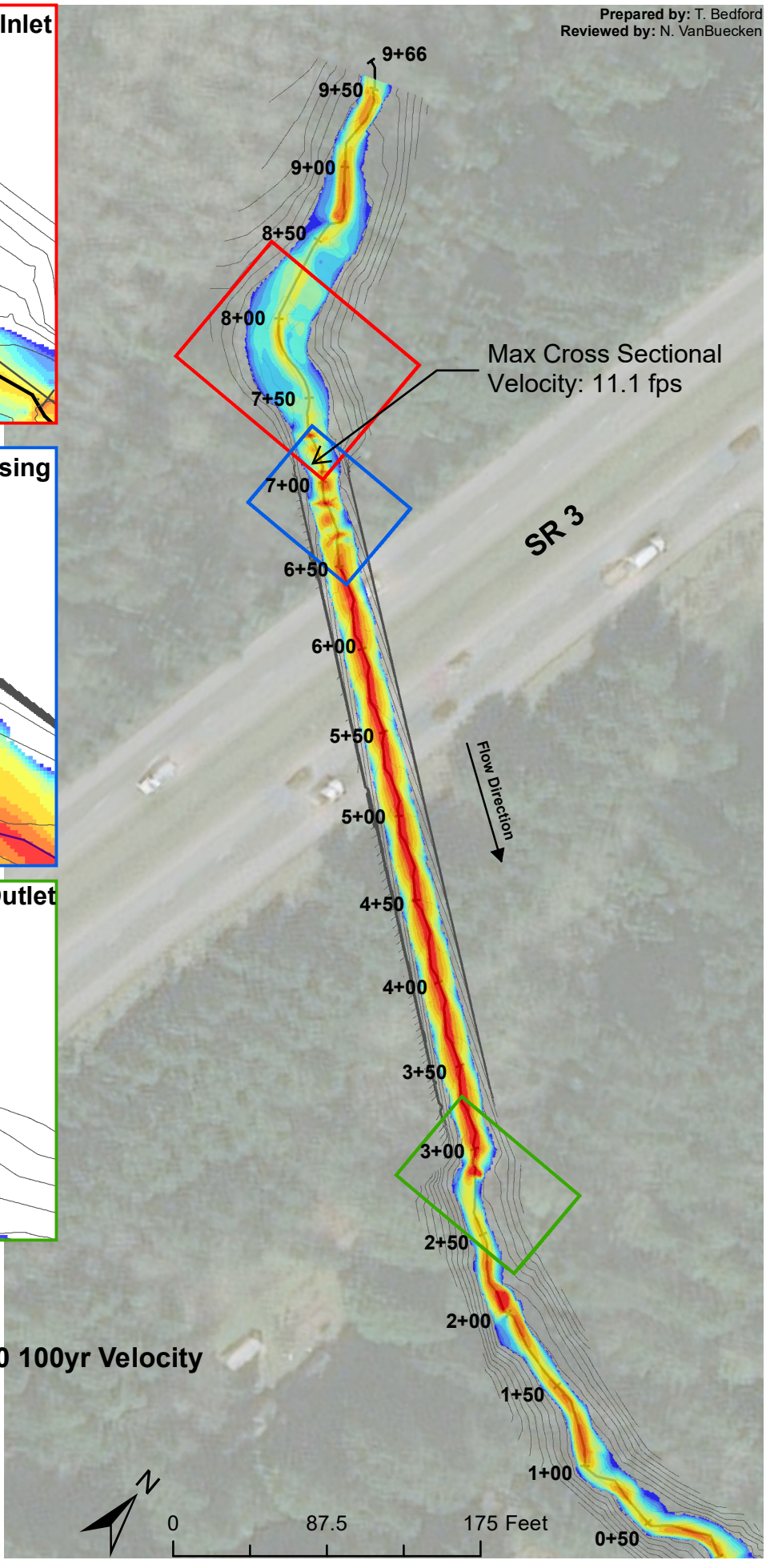
SR 3 MP 50.85 SF Johnson Creek - Model Outputs

Prepared by: T. Bedford
Reviewed by: N. VanBuecken









Proposed Conditions, Projected 2080 100yr Velocity

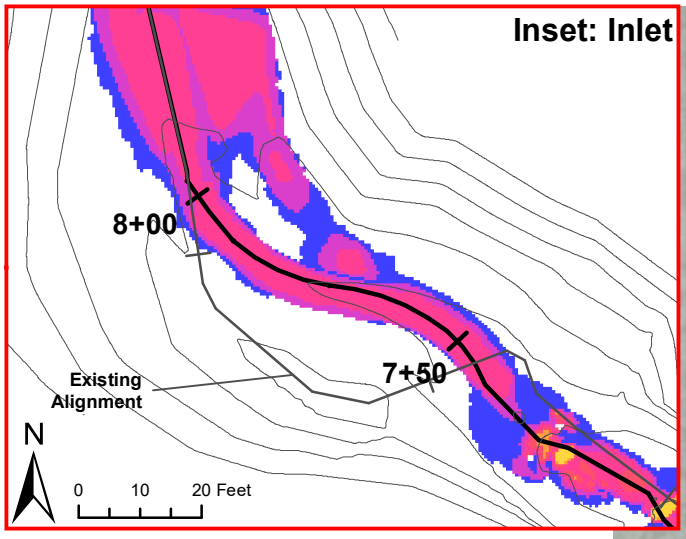
Velocity (fps)

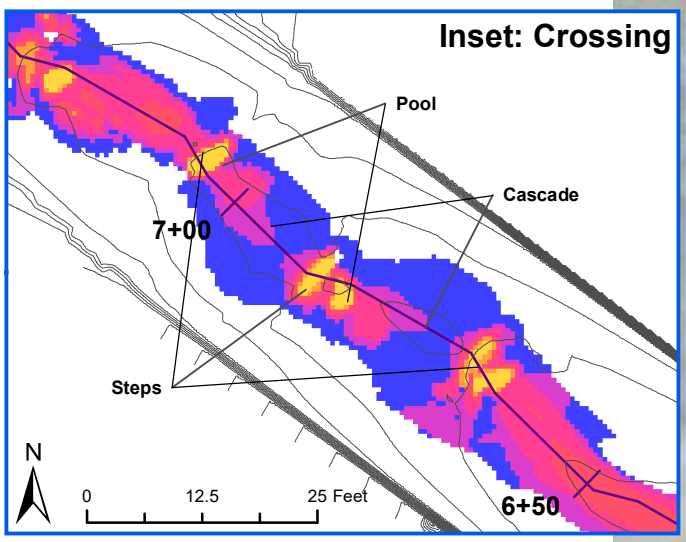
< 0.25	2.0 - 3	6.0 - 7
0.25 - 0.5	3.0 - 4	7.0 - 8
0.5 - 1	4.0 - 5	8.0 - 9
1.0 - 2	5.0 - 6	

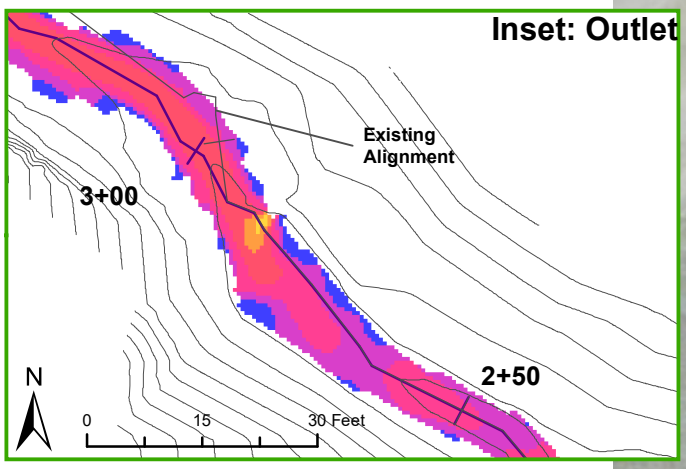
Appendix H

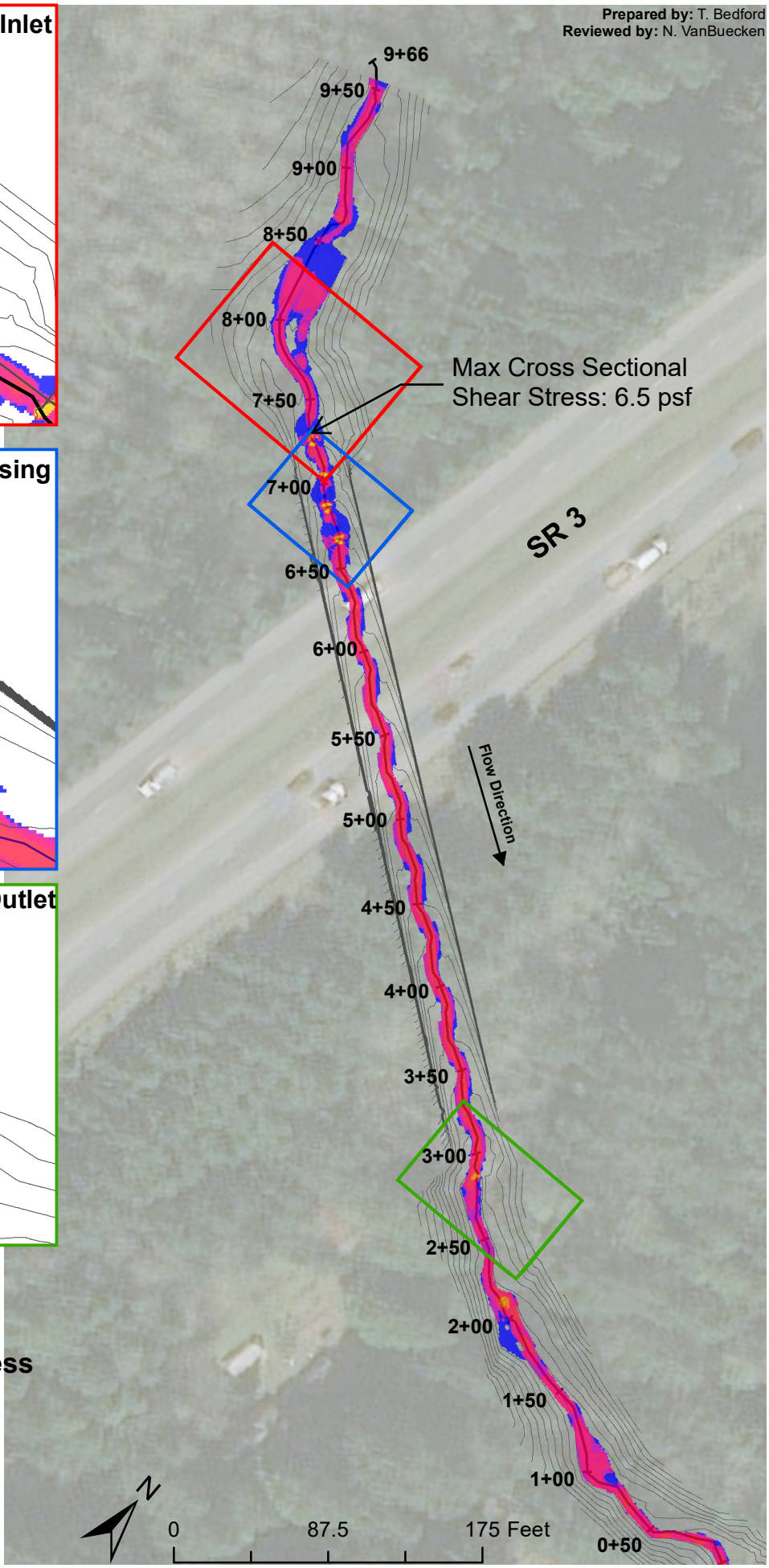
SR 3 MP 50.85 SF Johnson Creek - Model Outputs

Prepared by: T. Bedford
Reviewed by: N. VanBuecken









Proposed Conditions, 2yr Shear Stress

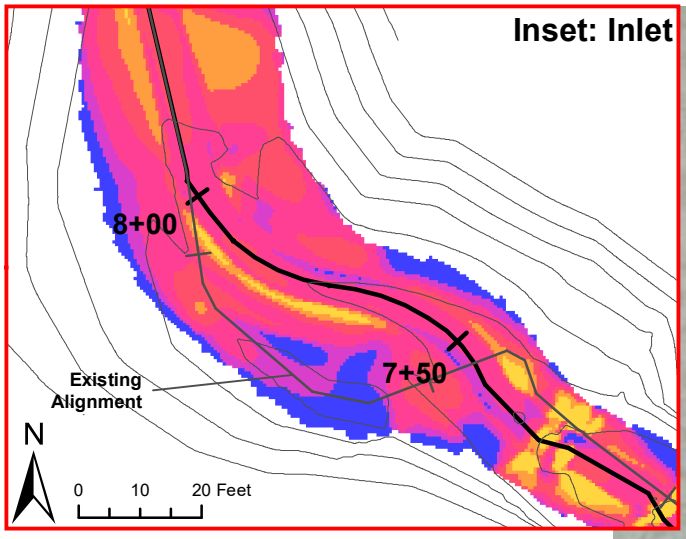
Shear Stress (psf)

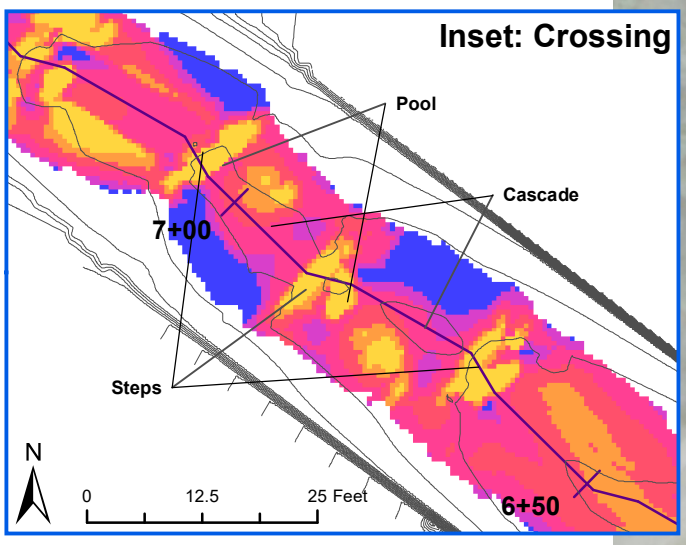
0 - 0.5	2.0 - 3.0
0.5 - 1.0	3.0 - 4.0
1.0 - 2.0	> 4.0

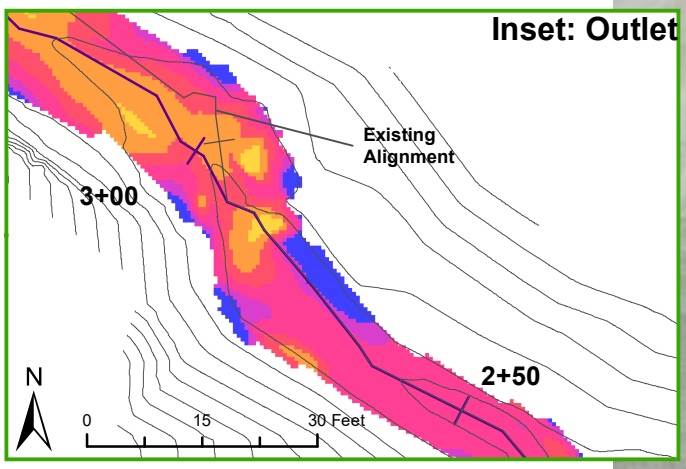
Appendix H

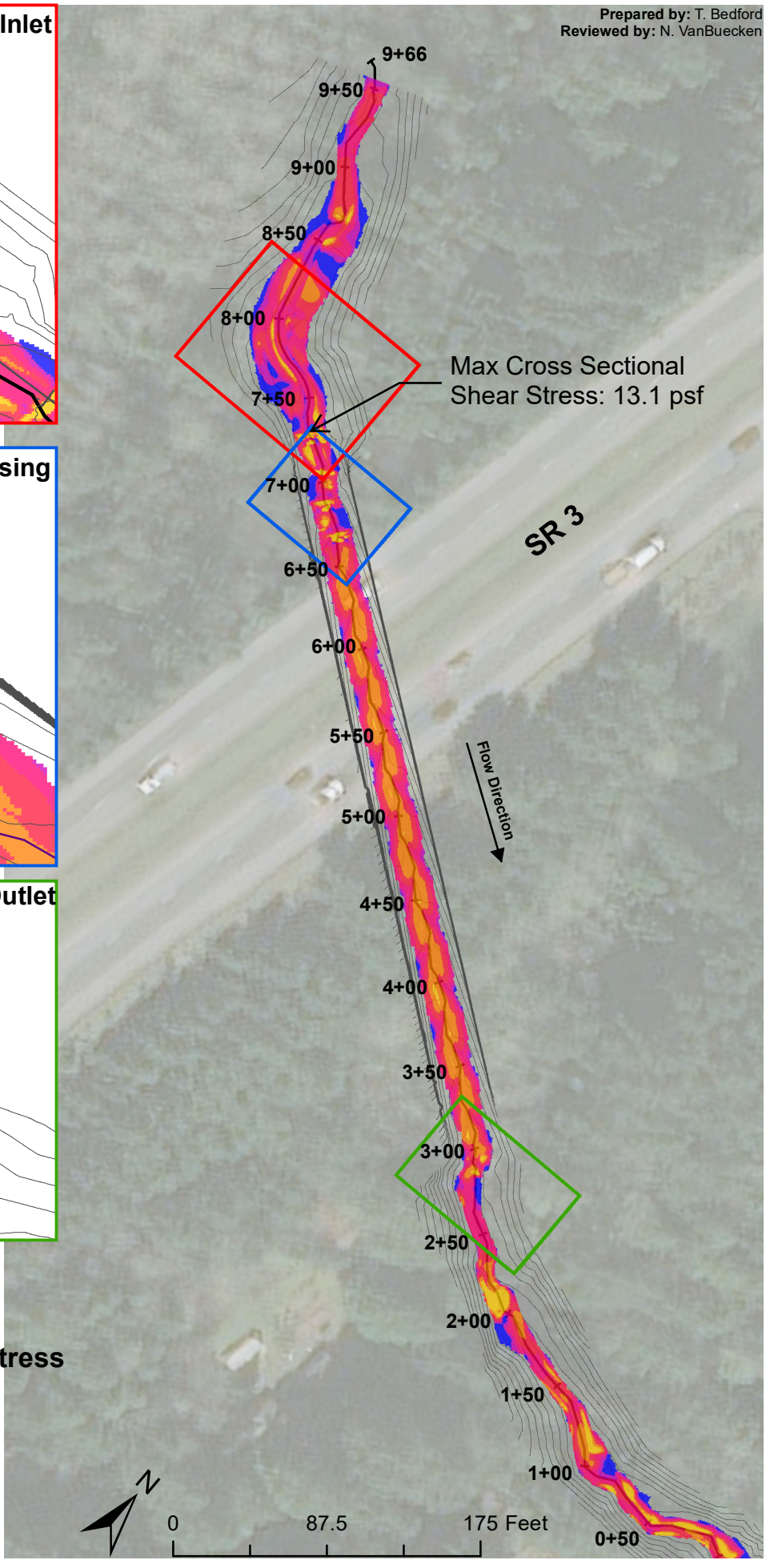
SR 3 MP 50.85 SF Johnson Creek - Model Outputs

Prepared by: T. Bedford
Reviewed by: N. VanBuecken









Proposed Conditions, 100yr Shear Stress

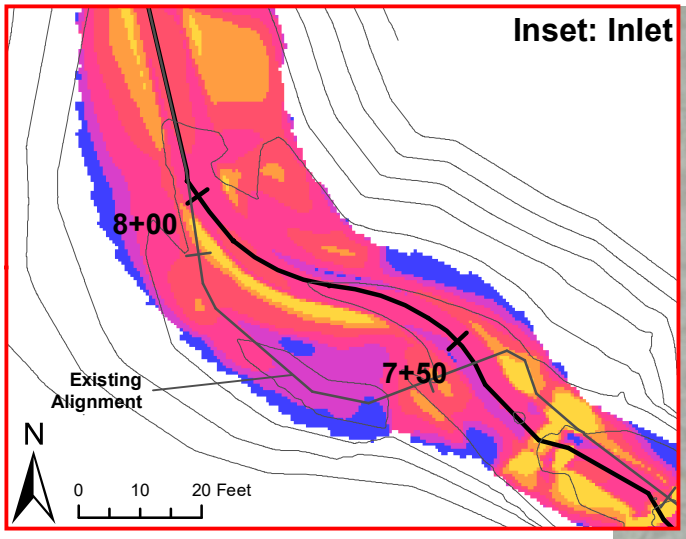
Shear Stress (psf)

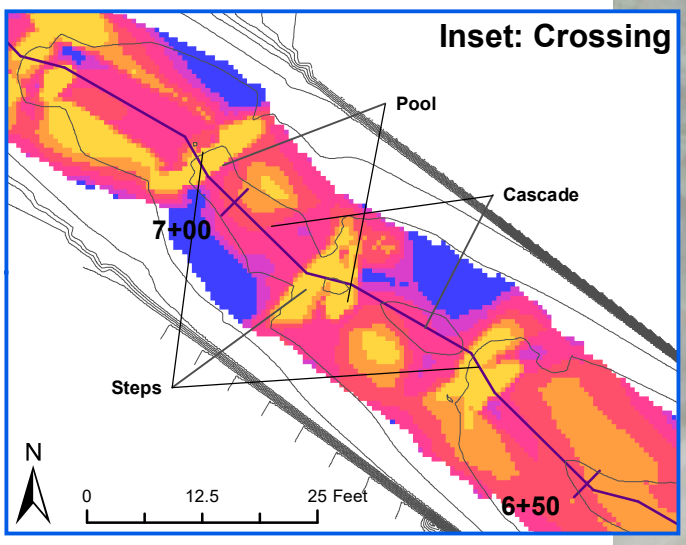
0 - 0.5	2.0 - 3.0
0.5 - 1.0	3.0 - 4.0
1.0 - 2.0	> 4.0

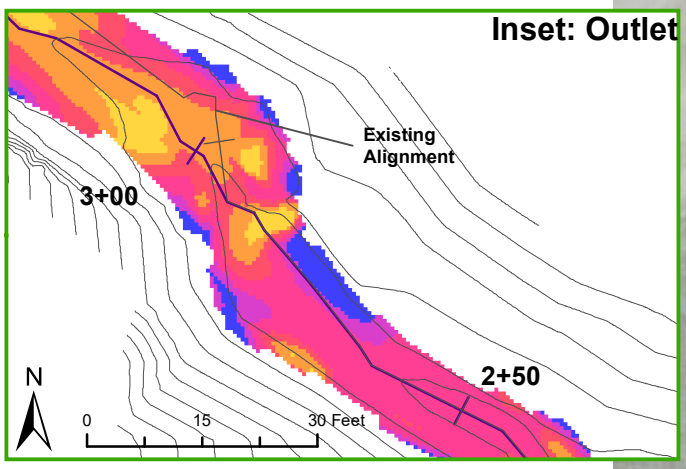
Appendix H

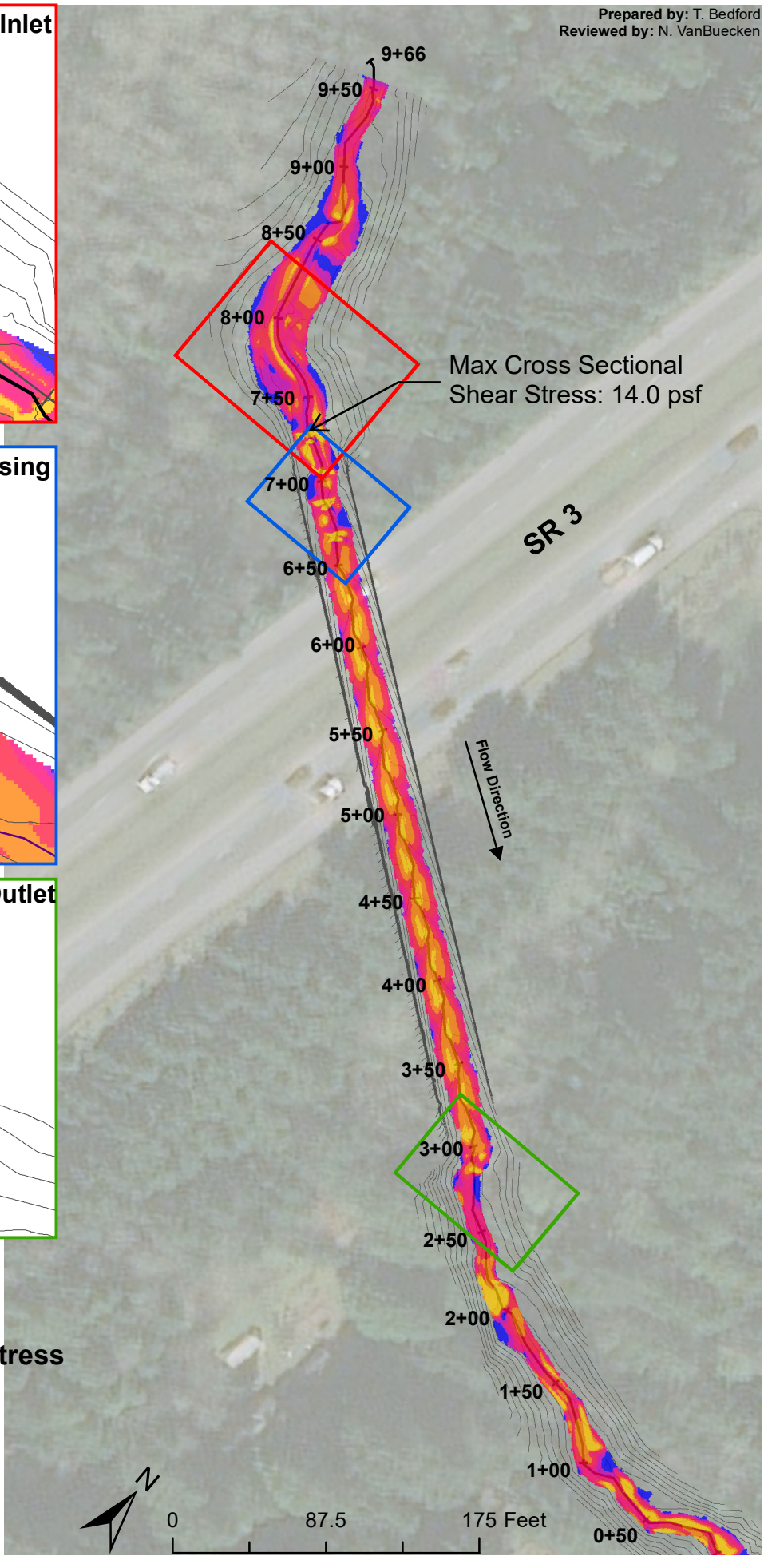
SR 3 MP 50.85 SF Johnson Creek - Model Outputs

Prepared by: T. Bedford
Reviewed by: N. VanBuecken









Proposed Conditions, 500yr Shear Stress

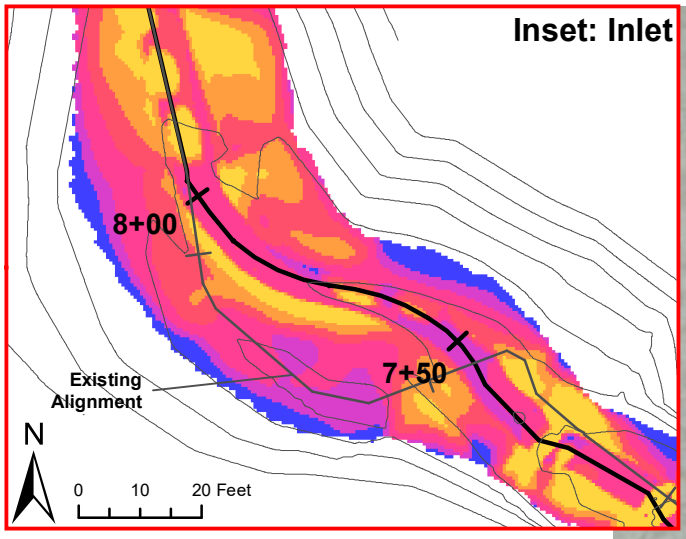
Shear Stress (psf)

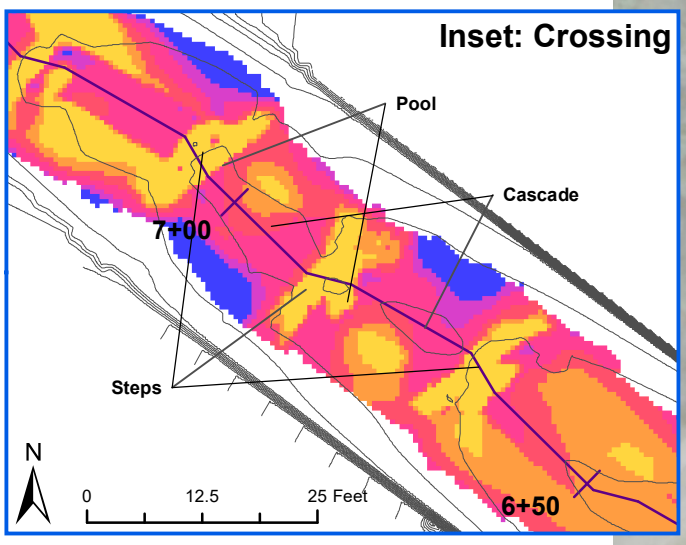
0 - 0.5	2.0 - 3.0
0.5 - 1.0	3.0 - 4.0
1.0 - 2.0	> 4.0

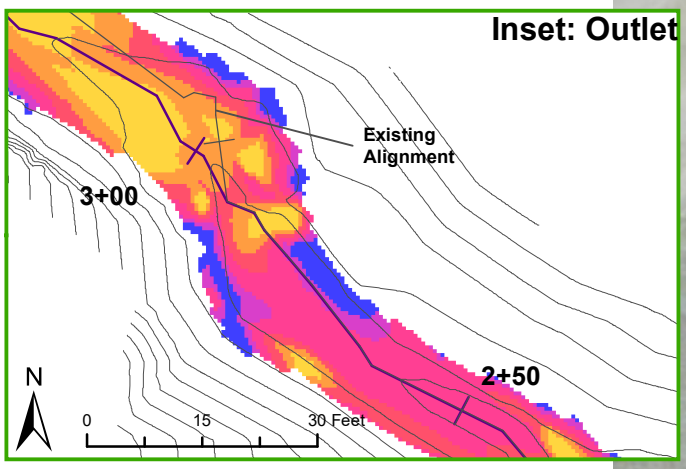
Appendix H

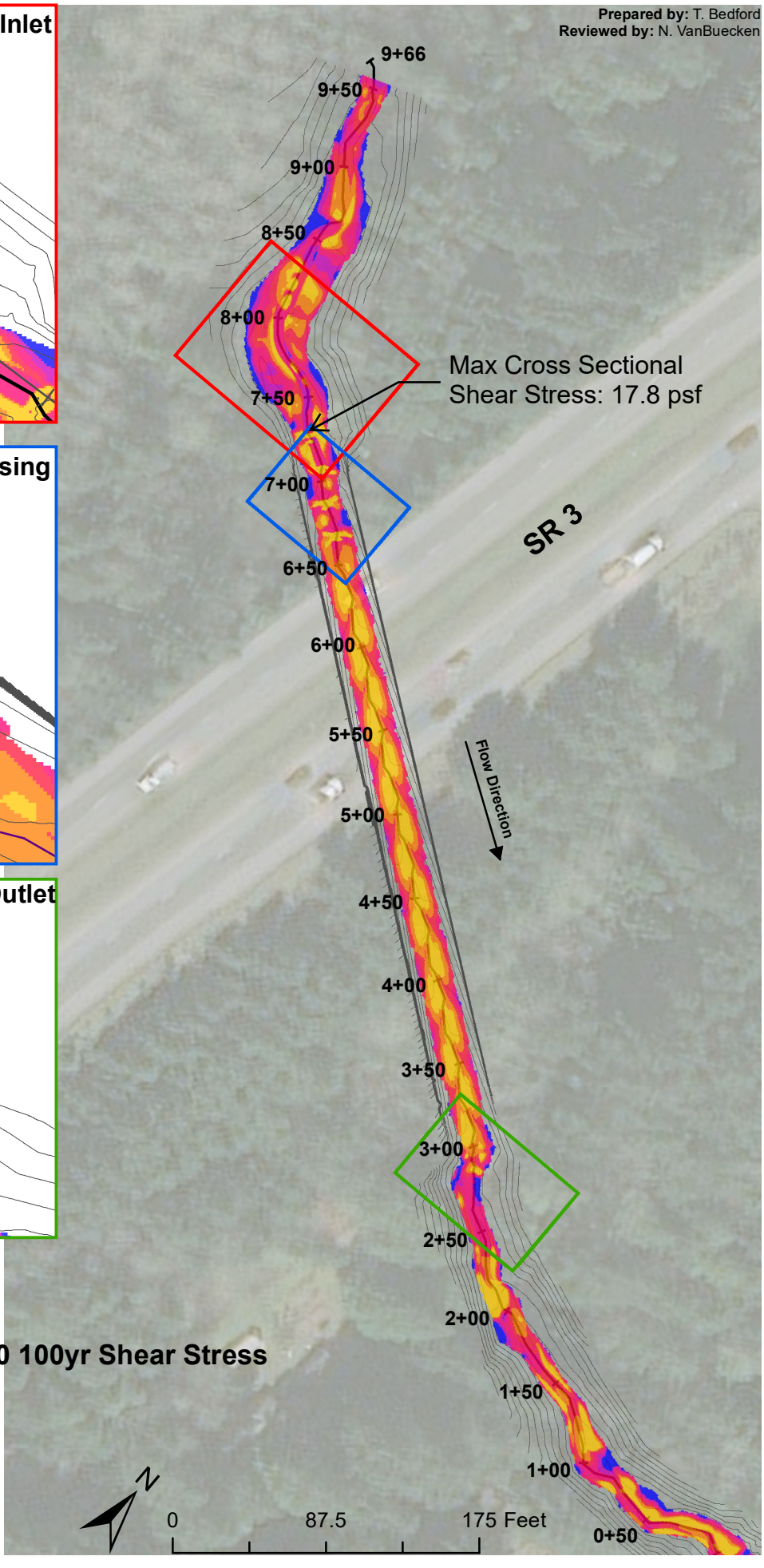
SR 3 MP 50.85 SF Johnson Creek - Model Outputs

Prepared by: T. Bedford
Reviewed by: N. VanBuecken





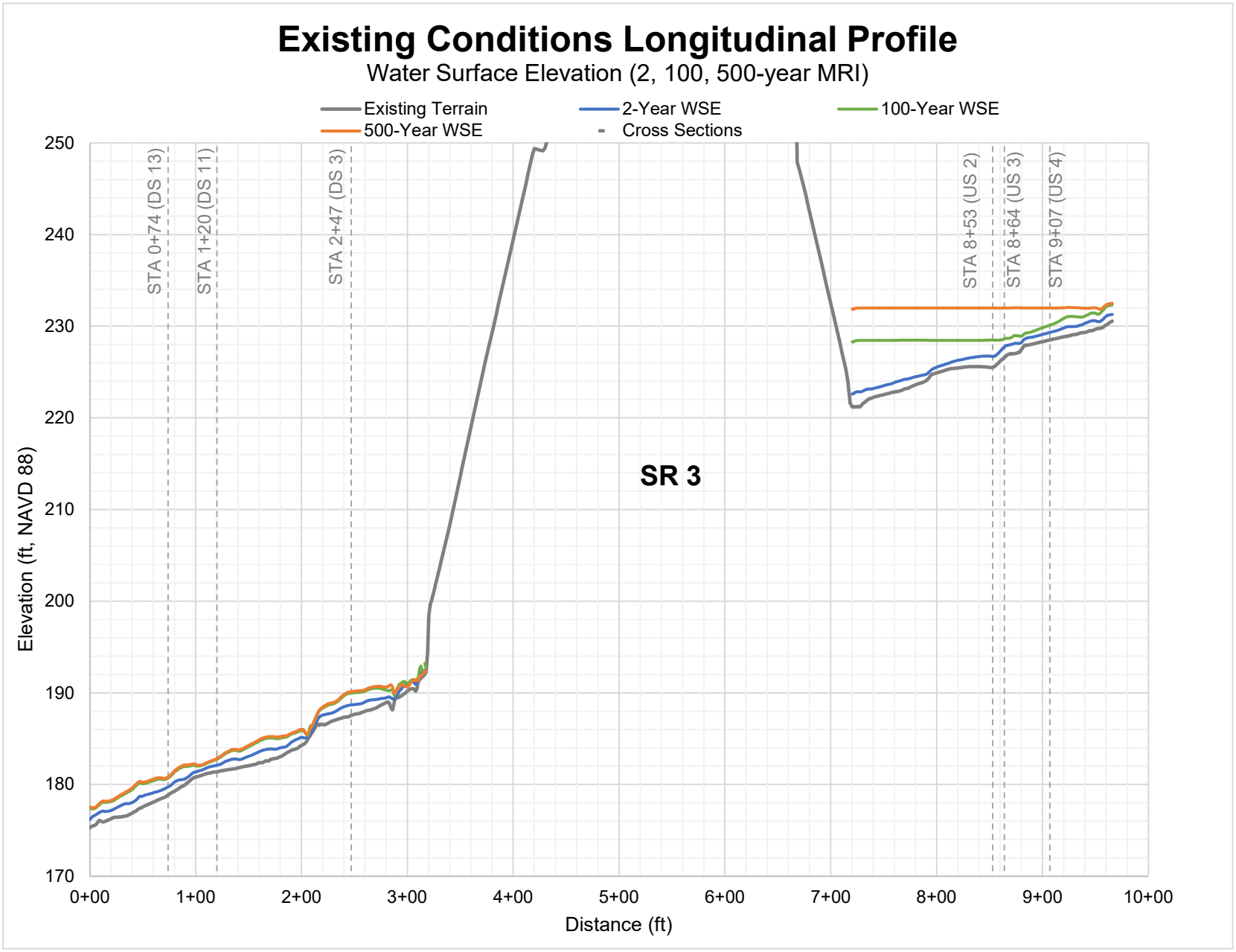


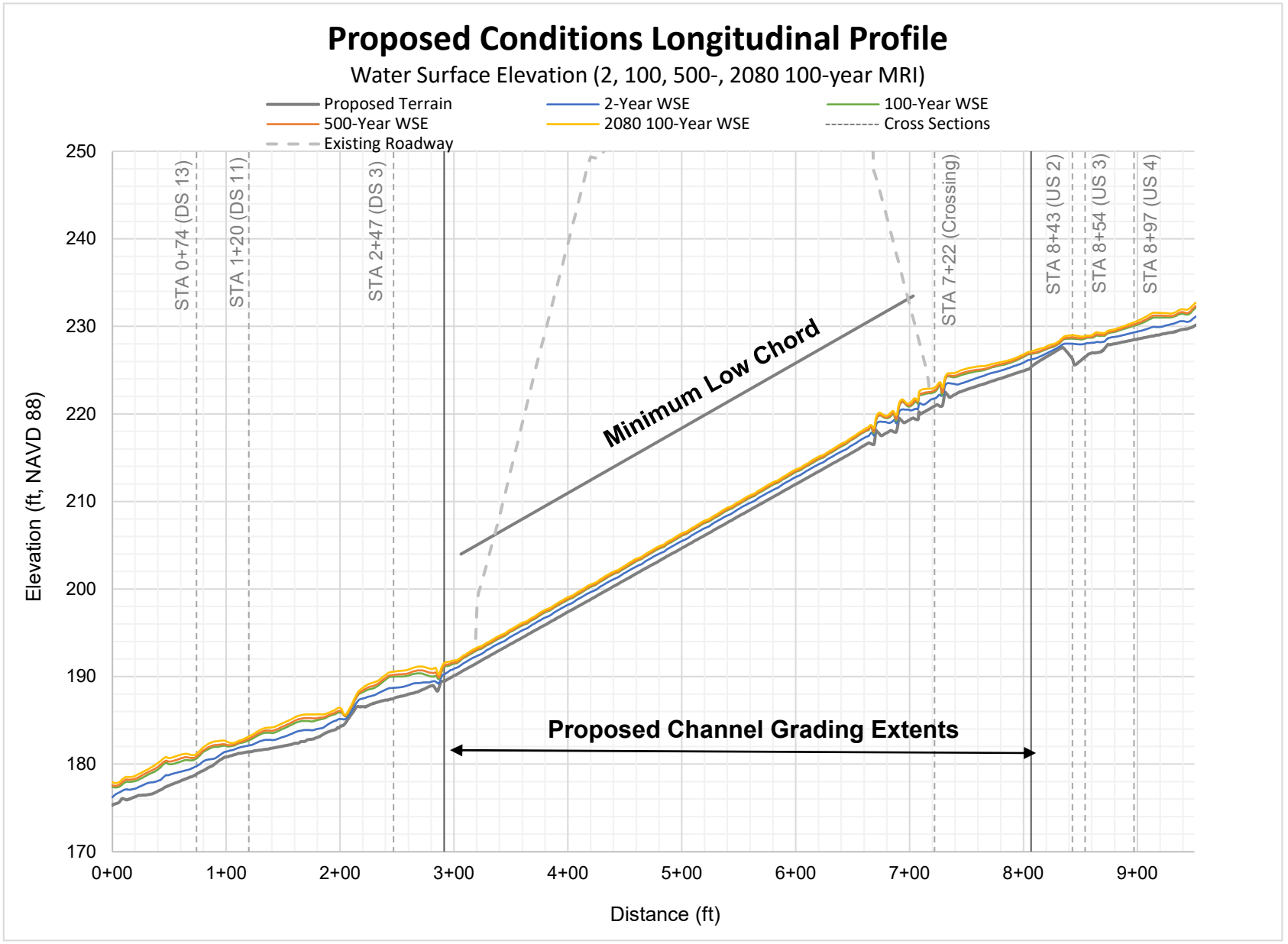


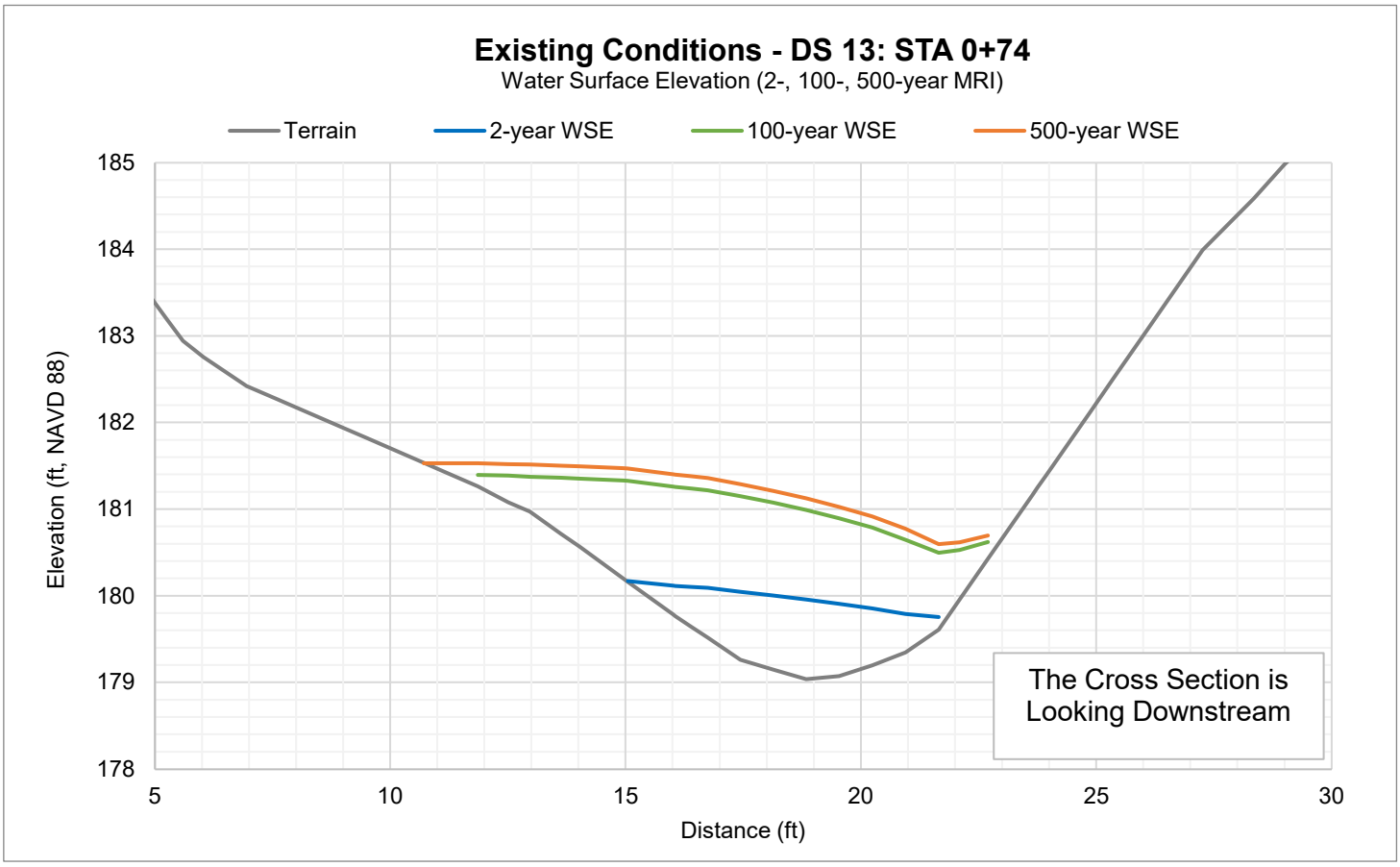
Proposed Conditions, Projected 2080 100yr Shear Stress

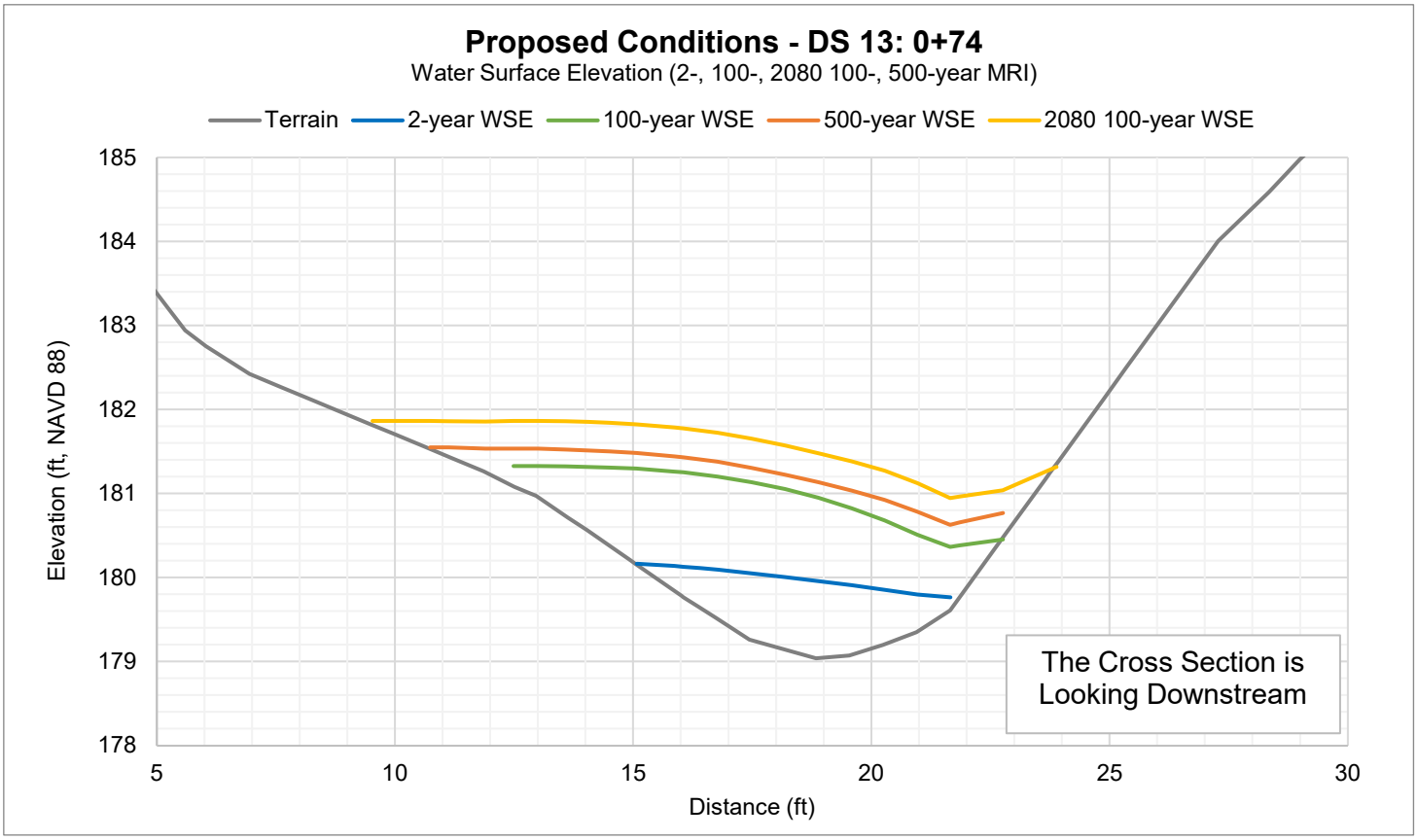
Shear Stress (psf)

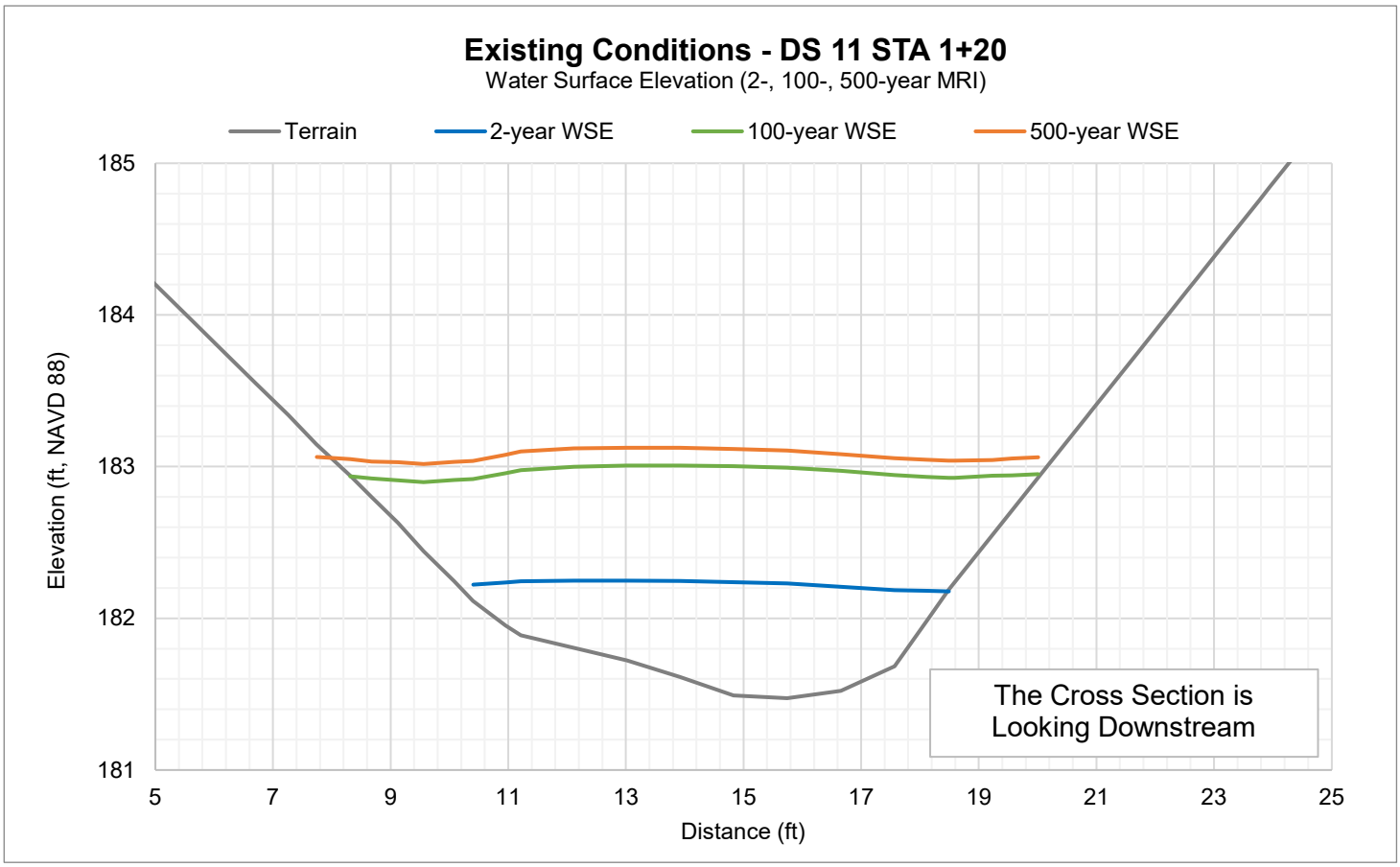
0 - 0.5	2.0 - 3.0
0.5 - 1.0	3.0 - 4.0
1.0 - 2.0	> 4.0

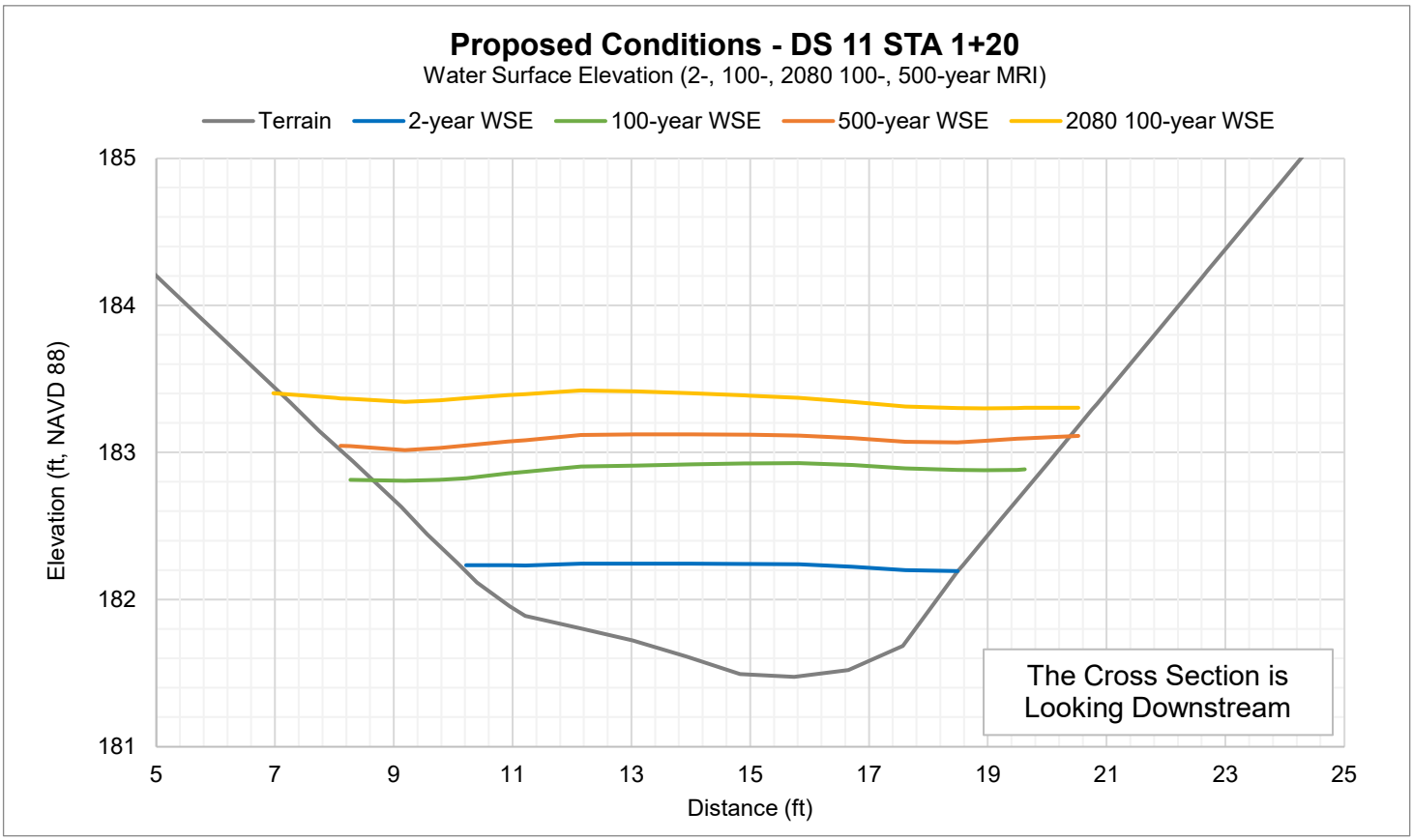

Existing Conditions Longitudinal Profile
Water Surface Elevation (2, 100, 500-year MRI)
Existing Terrain
2-Year WSE
100-Year WSE
500-Year WSE
Cross Sections
STA 0+74 (DS 13)
STA 1+20 (DS 11)
STA 2+47 (DS 3)
STA 8+53 (US 2)
STA 8+64 (US 3)
STA 9+07 (US 4)
SR 3
Elevation (ft, NAVD 88)
250
240
230
220
210
200
190
180
170
0+00
1+00
2+00
3+00
4+00
5+00
6+00
7+00
8+00
9+00
10+00
Distance (ft)

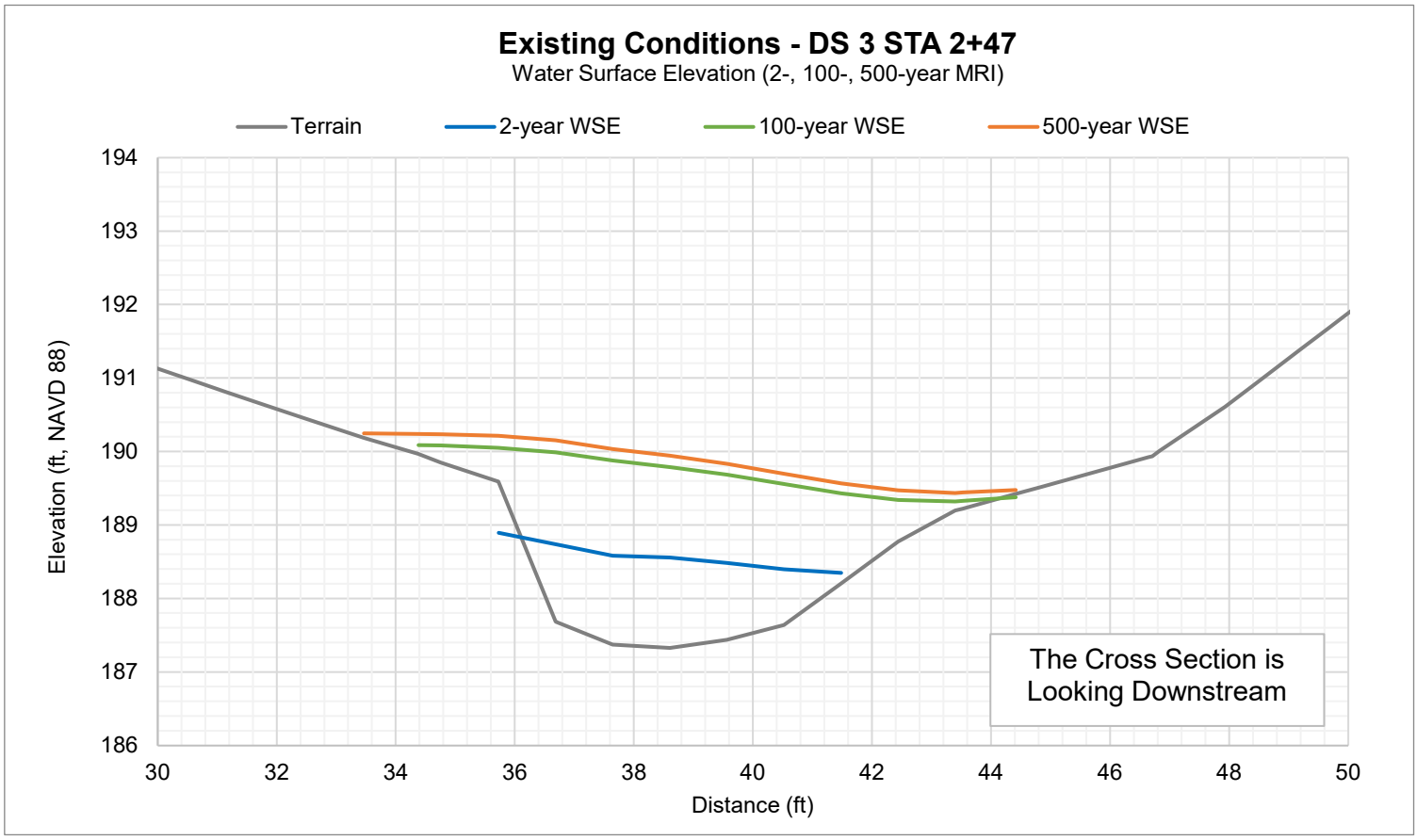

Proposed Conditions Longitudinal Profile
Water Surface Elevation (2, 100, 500-, 2080 100-year MRI)
Proposed Terrain
2-Year WSE
100-Year WSE
500-Year WSE
2080 100-Year WSE
Cross Sections
Existing Roadway
STA 0+74 (DS 13)
STA 1+20 (DS 11)
STA 2+47 (DS 3)
STA 7+22 (Crossing)
STA 8+43 (US 2)
STA 8+54 (US 3)
STA 8+97 (US 4)
Minimum Low Chord
Proposed Channel Grading Extents
Elevation (ft, NAVD 88)
250
240
230
220
210
200
190
180
170
0+00
1+00
2+00
3+00
4+00
5+00
6+00
7+00
8+00
9+00
Distance (ft)

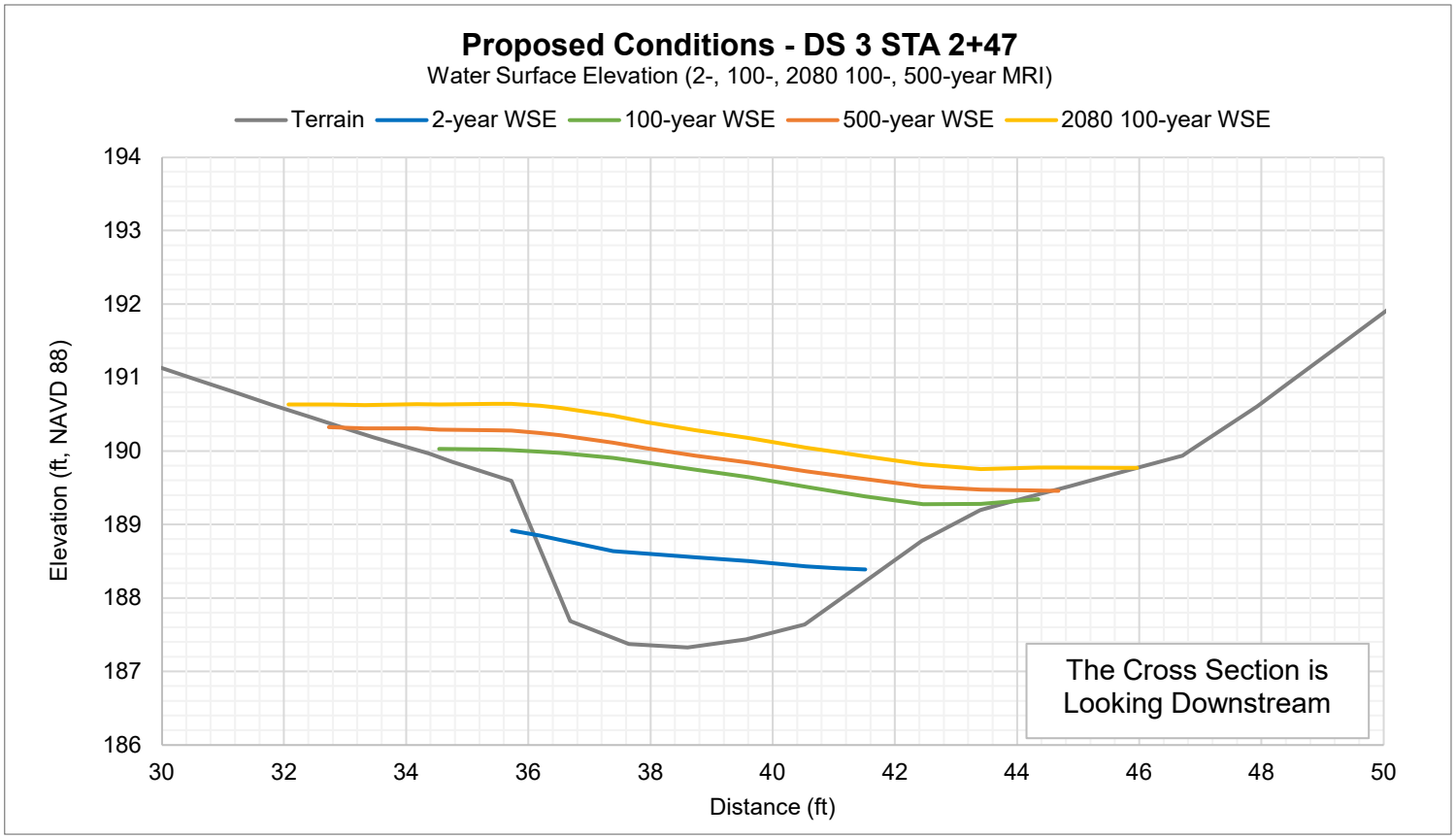

Existing Conditions - DS 13: STA 0+74
Water Surface Elevation (2-, 100-, 500-year MRI)
Terrain
2-year WSE
100-year WSE
500-year WSE
Elevation (ft, NAVD 88)
185
184
183
182
181
180
179
178
5
10
15
20
25
30
Distance (ft)
The Cross Section is Looking Downstream

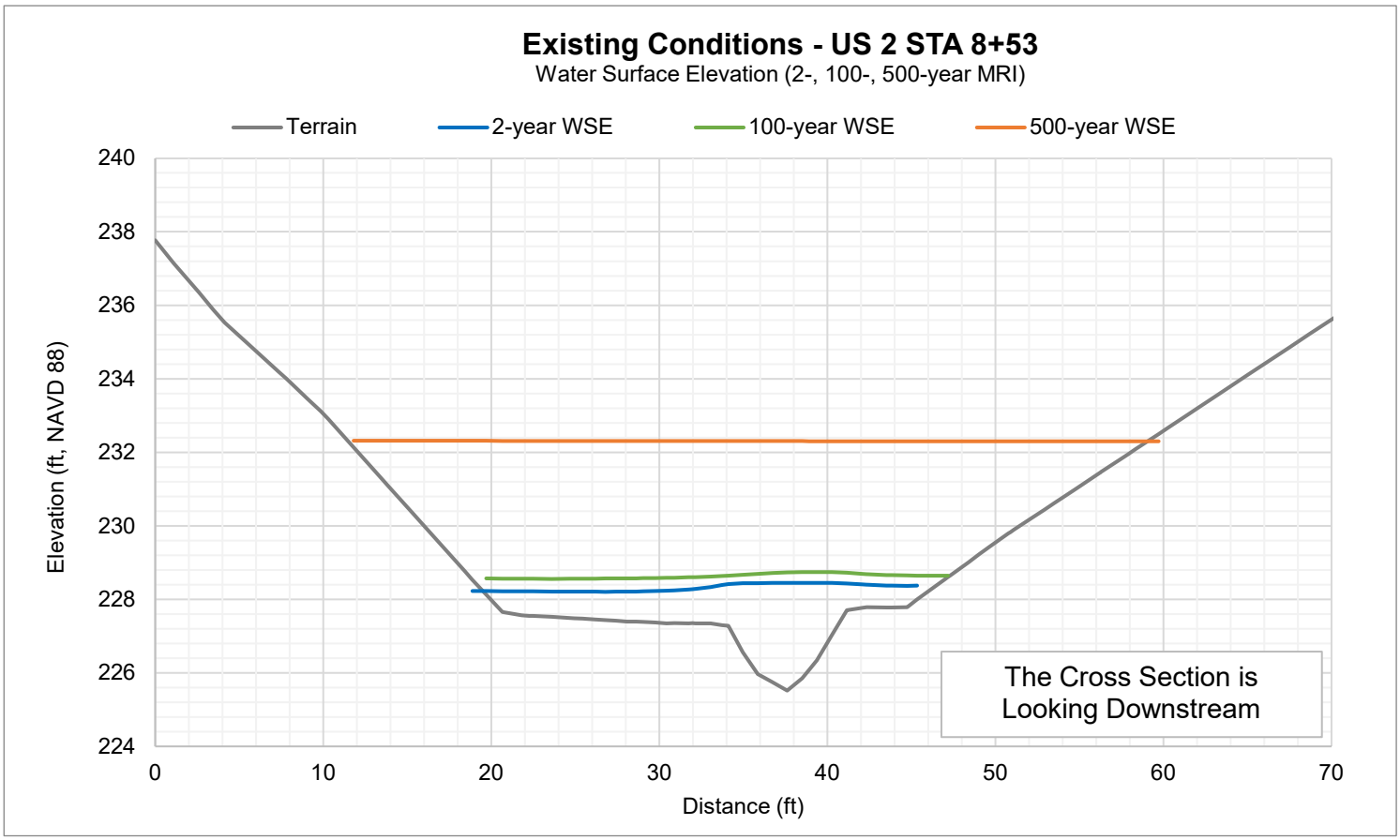

Proposed Conditions - DS 13: 0+74
Water Surface Elevation (2-, 100-, 2080 100-, 500-year MRI)
Terrain
2-year WSE
100-year WSE
500-year WSE
2080 100-year WSE
Elevation (ft, NAVD 88)
185
184
183
182
181
180
179
178
5
10
15
20
25
30
Distance (ft)
The Cross Section is Looking Downstream

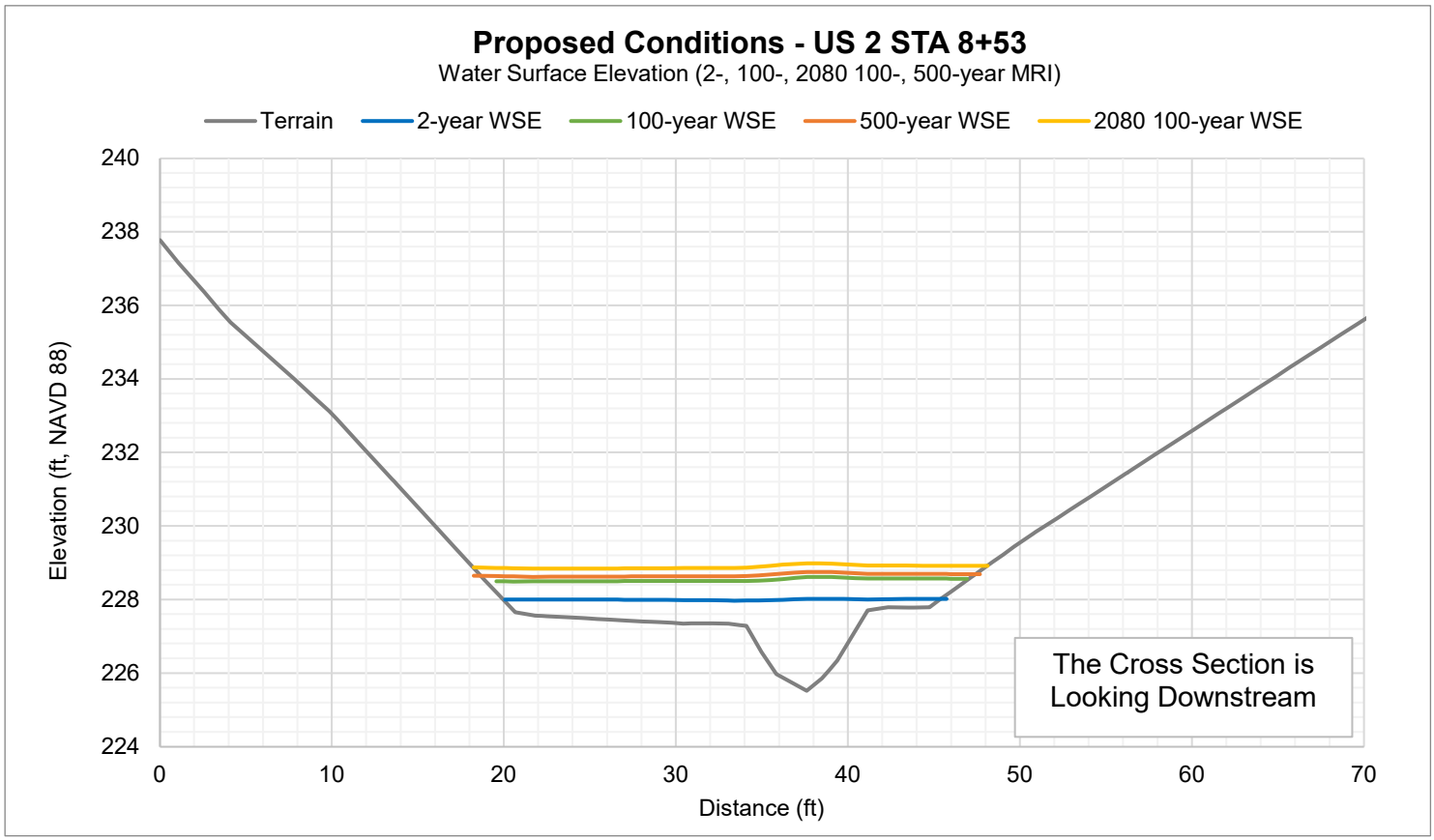

Existing Conditions - DS 11 STA 1+20
Water Surface Elevation (2-, 100-, 500-year MRI)
Terrain
2-year WSE
100-year WSE
500-year WSE
Elevation (ft, NAVD 88)
185
184
183
182
181
5
7
9
11
13
15
17
19
21
23
25
Distance (ft)
The Cross Section is Looking Downstream

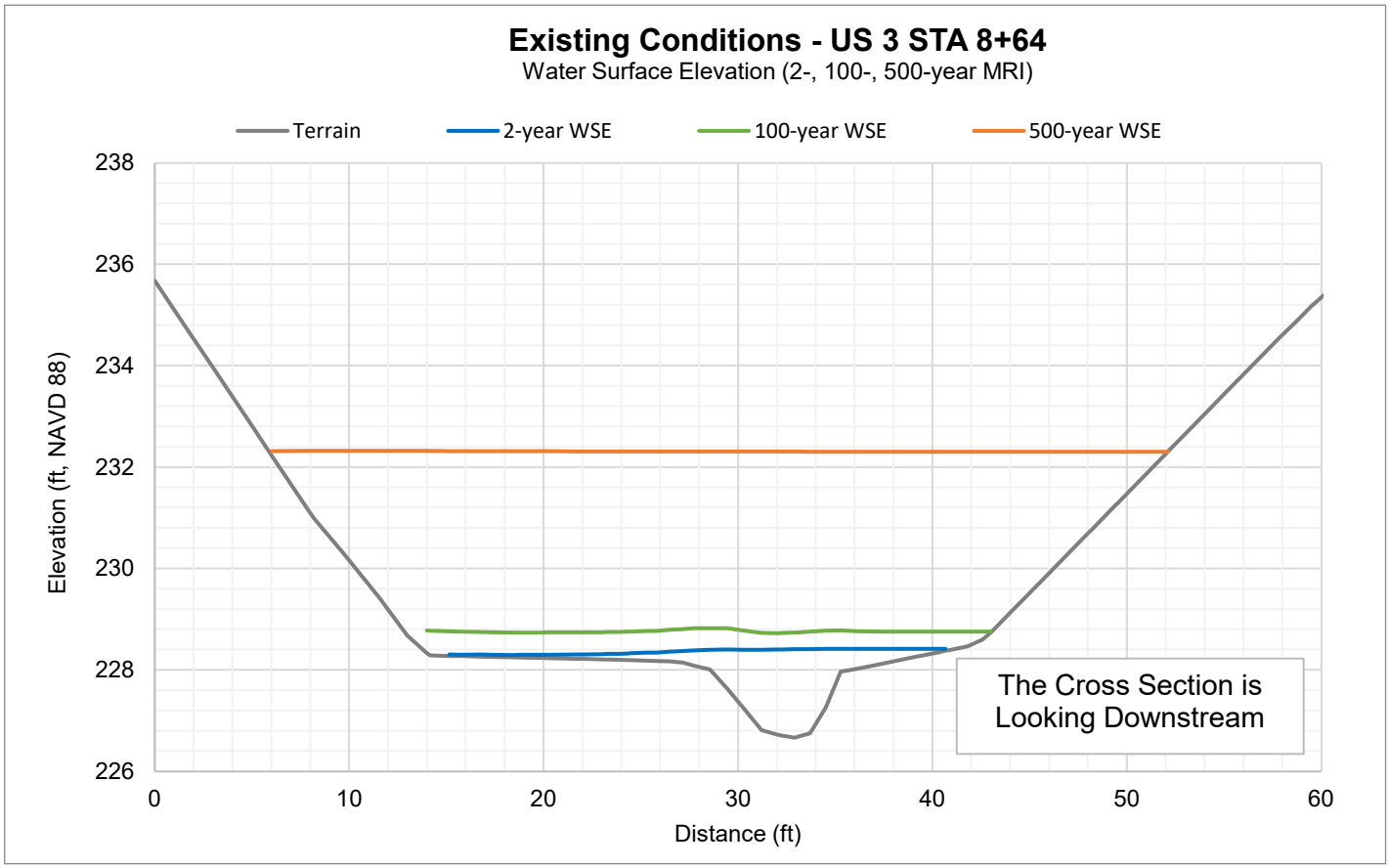

Proposed Conditions - DS 11 STA 1+20
Water Surface Elevation (2-, 100-, 2080 100-, 500-year MRI)
Terrain
2-year WSE
100-year WSE
500-year WSE
2080 100-year WSE
Elevation (ft, NAVD 88)
185
184
183
182
181
5
7
9
11
13
15
17
19
21
23
25
Distance (ft)
The Cross Section is Looking Downstream

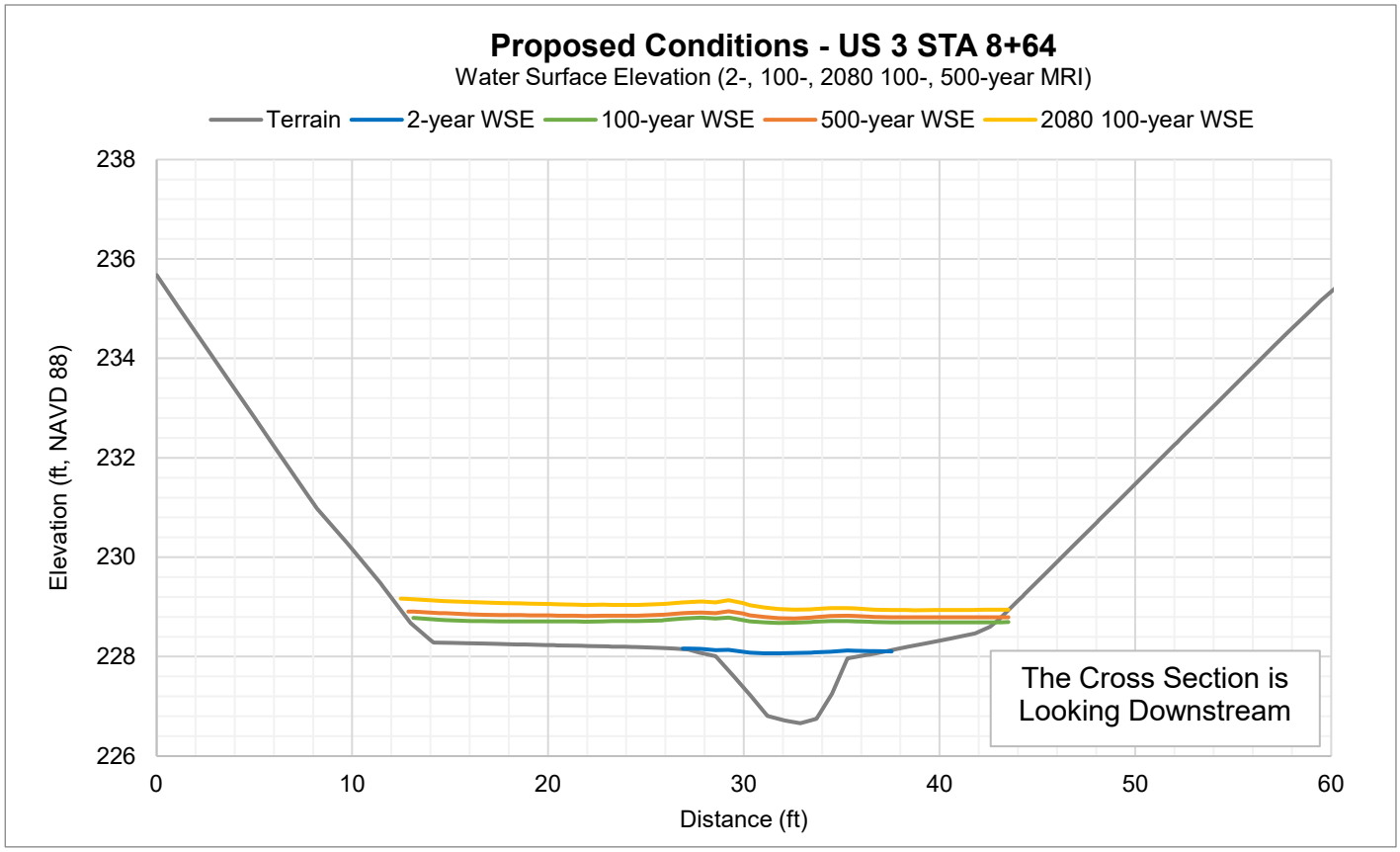

Existing Conditions - DS 3 STA 2+47
Water Surface Elevation (2-, 100-, 500-year MRI)
Terrain
2-year WSE
100-year WSE
500-year WSE
Elevation (ft, NAVD 88)
194
193
192
191
190
189
188
187
186
30
32
34
36
38
40
42
44
46
48
50
Distance (ft)
The Cross Section is Looking Downstream

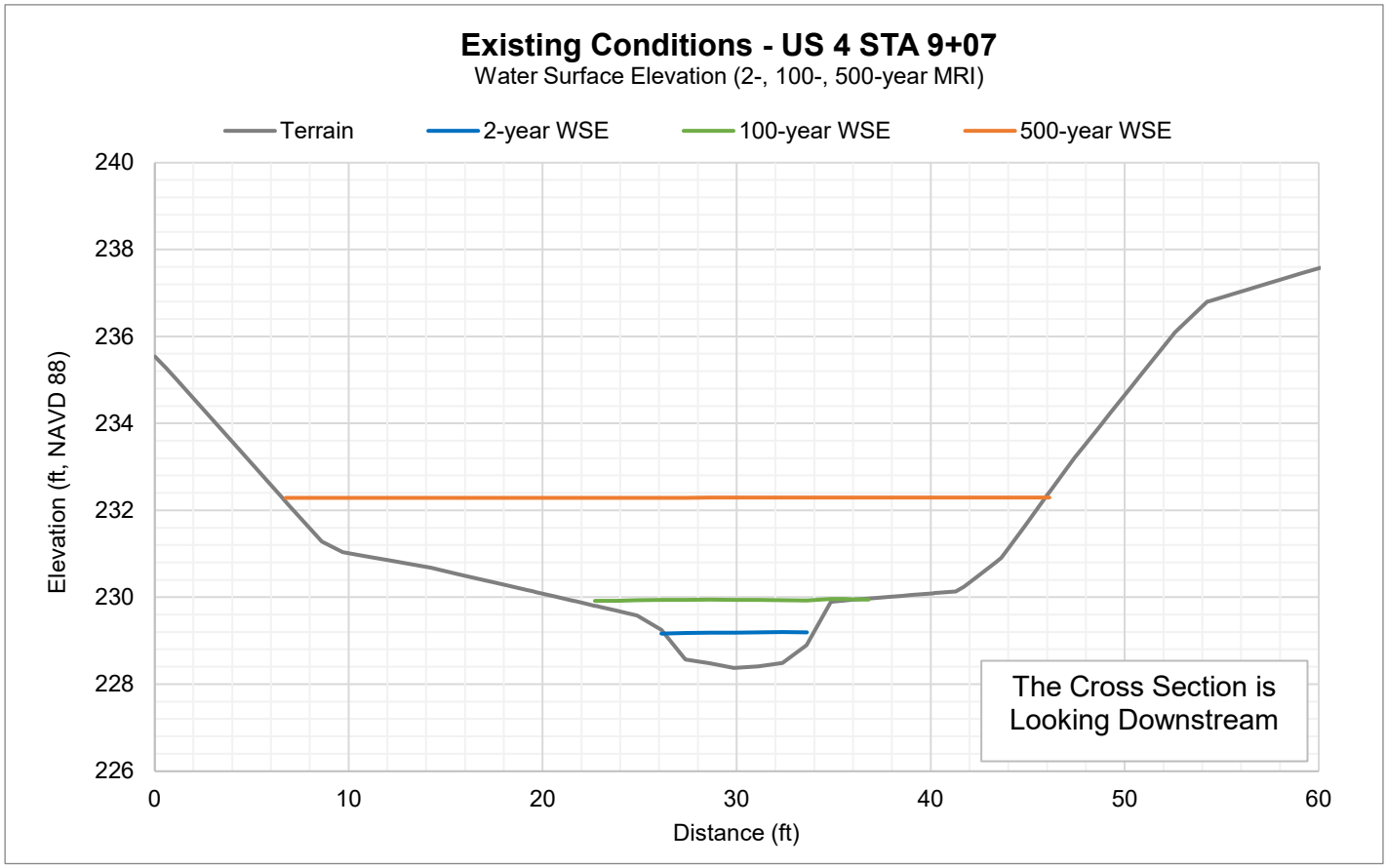

Proposed Conditions - DS 3 STA 2+47
Water Surface Elevation (2-, 100-, 2080 100-, 500-year MRI)
Terrain
2-year WSE
100-year WSE
500-year WSE
2080 100-year WSE
Elevation (ft, NAVD 88)
194
193
192
191
190
189
188
187
186
30
32
34
36
38
40
42
44
46
48
50
Distance (ft)
The Cross Section is Looking Downstream

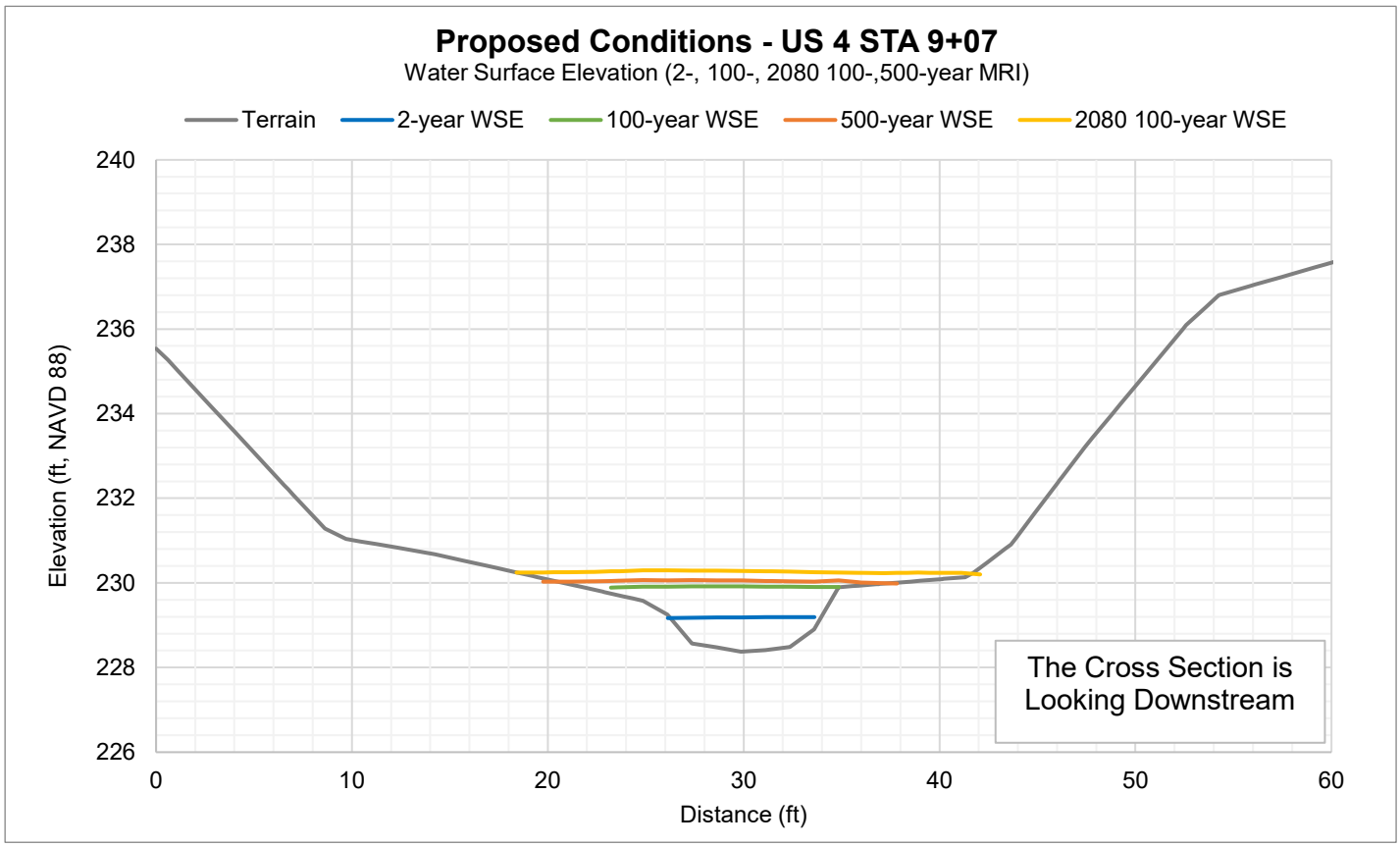

Existing Conditions - US 2 STA 8+53
Water Surface Elevation (2-, 100-, 500-year MRI)
Terrain
2-year WSE
100-year WSE
500-year WSE
Elevation (ft, NAVD 88)
240
238
236
234
232
230
228
226
224
0
10
20
30
40
50
60
70
Distance (ft)
The Cross Section is Looking Downstream

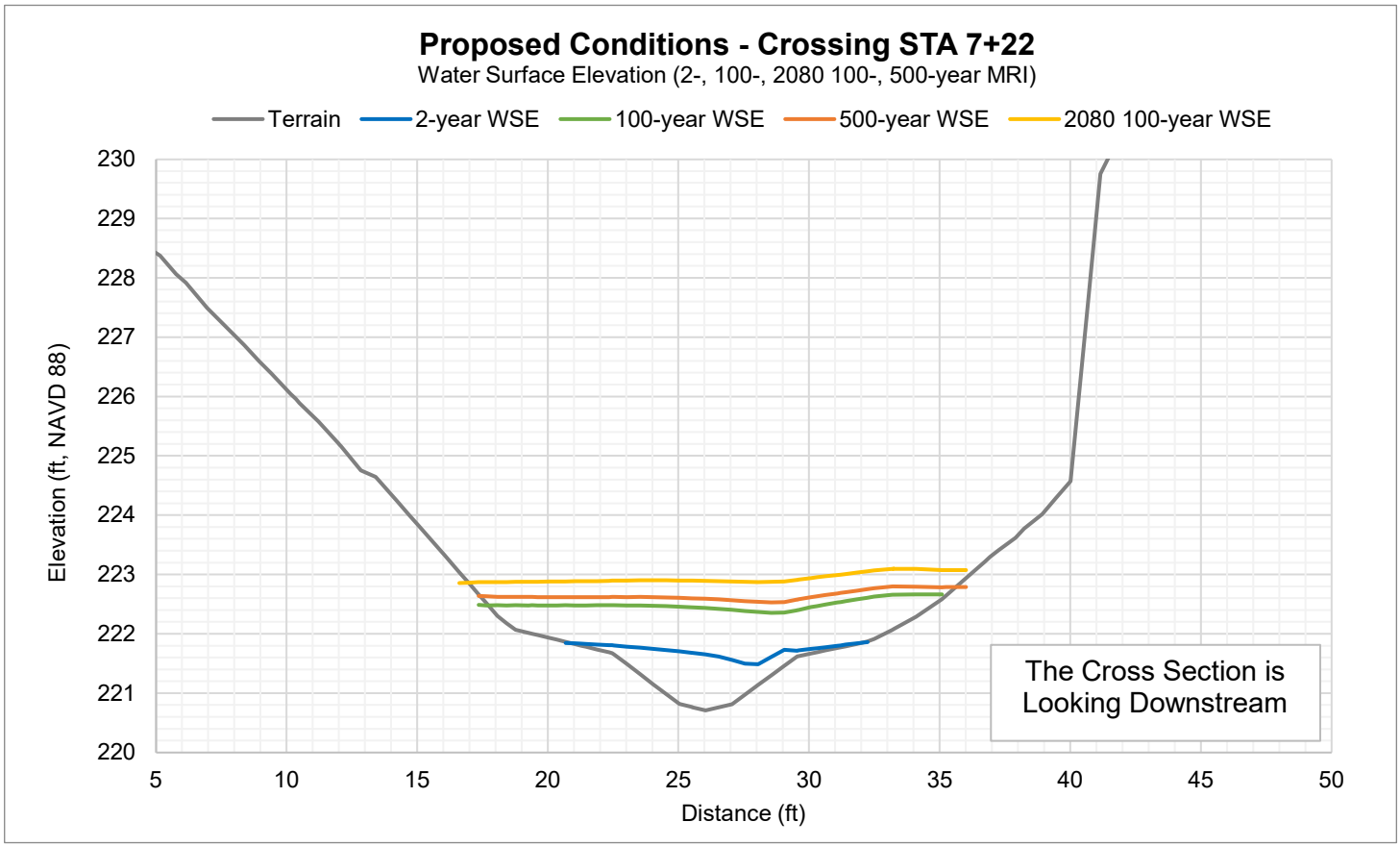

Proposed Conditions - US 2 STA 8+53
Water Surface Elevation (2-, 100-, 2080 100-, 500-year MRI)
Terrain
2-year WSE
100-year WSE
500-year WSE
2080 100-year WSE
Elevation (ft, NAVD 88)
240
238
236
234
232
230
228
226
224
0
10
20
30
40
50
60
70
Distance (ft)
The Cross Section is Looking Downstream


Existing Conditions - US 3 STA 8+64
Water Surface Elevation (2-, 100-, 500-year MRI)
Terrain
2-year WSE
100-year WSE
500-year WSE
Elevation (ft, NAVD 88)
238
236
234
232
230
228
226
0
10
20
30
40
50
60
Distance (ft)
The Cross Section is Looking Downstream


Proposed Conditions - US 3 STA 8+64
Water Surface Elevation (2-, 100-, 2080 100-, 500-year MRI)
Terrain
2-year WSE
100-year WSE
500-year WSE
2080 100-year WSE
Elevation (ft, NAVD 88)
238
236
234
232
230
228
226
0
10
20
30
40
50
60
Distance (ft)
The Cross Section is Looking Downstream


Existing Conditions - US 4 STA 9+07
Water Surface Elevation (2-, 100-, 500-year MRI)
Terrain
2-year WSE
100-year WSE
500-year WSE
Elevation (ft, NAVD 88)
240
238
236
234
232
230
228
226
0
10
20
30
40
50
60
Distance (ft)
The Cross Section is Looking Downstream

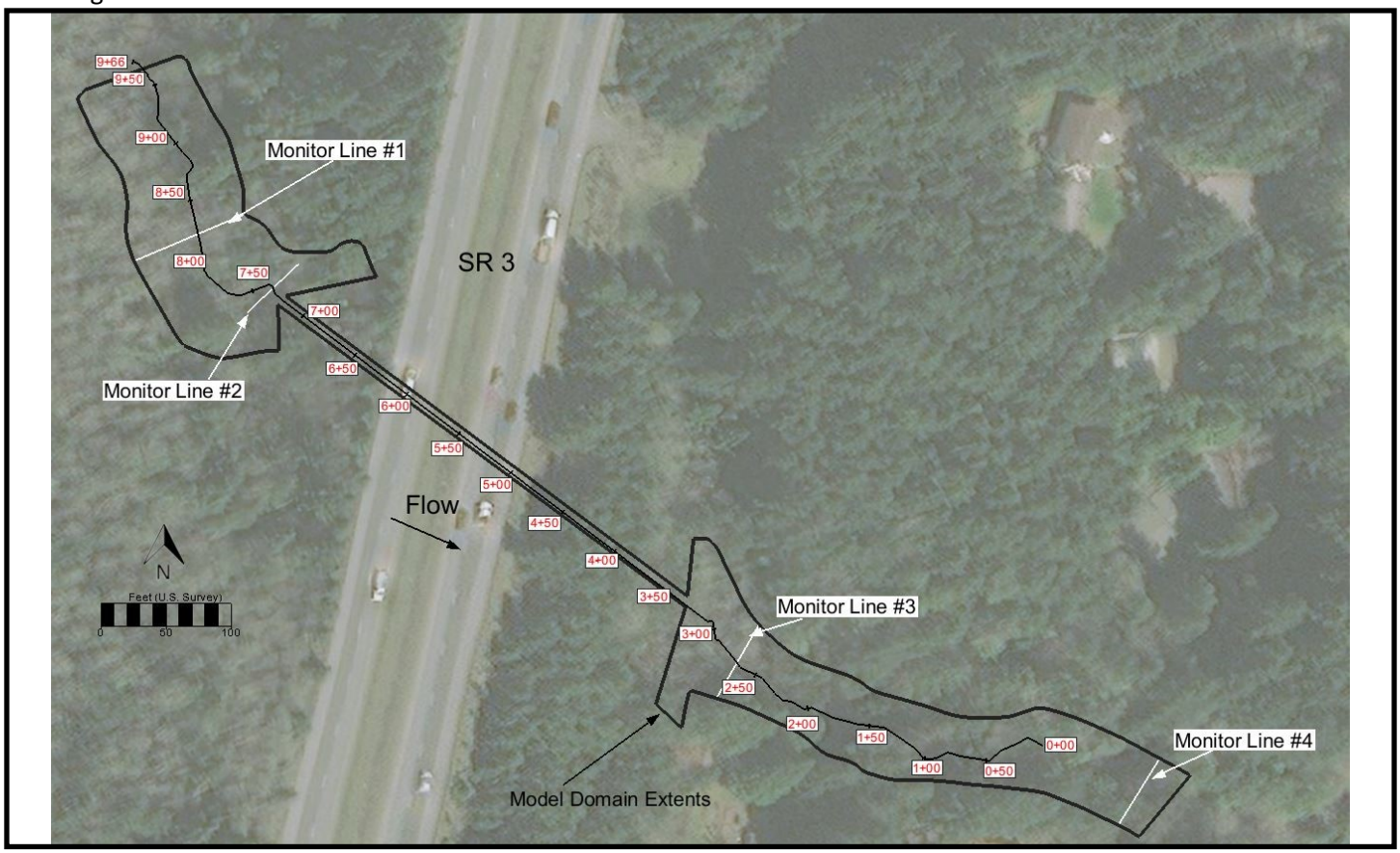

Proposed Conditions - US 4 STA 9+07
Water Surface Elevation (2-, 100-, 2080 100-,500-year MRI)
Terrain
2-year WSE
100-year WSE
500-year WSE
2080 100-year WSE
Elevation (ft, NAVD 88)
240
238
236
234
232
230
228
226
0
10
20
30
40
50
60
Distance (ft)
The Cross Section is Looking Downstream


Proposed Conditions - Crossing STA 7+22
Water Surface Elevation (2-, 100-, 2080 100-, 500-year MRI)
Terrain
2-year WSE
100-year WSE
500-year WSE
2080 100-year WSE
Elevation (ft, NAVD 88)
230
229
228
227
226
225
224
223
222
221
220
5
10
15
20
25
30
35
40
45
50
Distance (ft)
The Cross Section is Looking Downstream

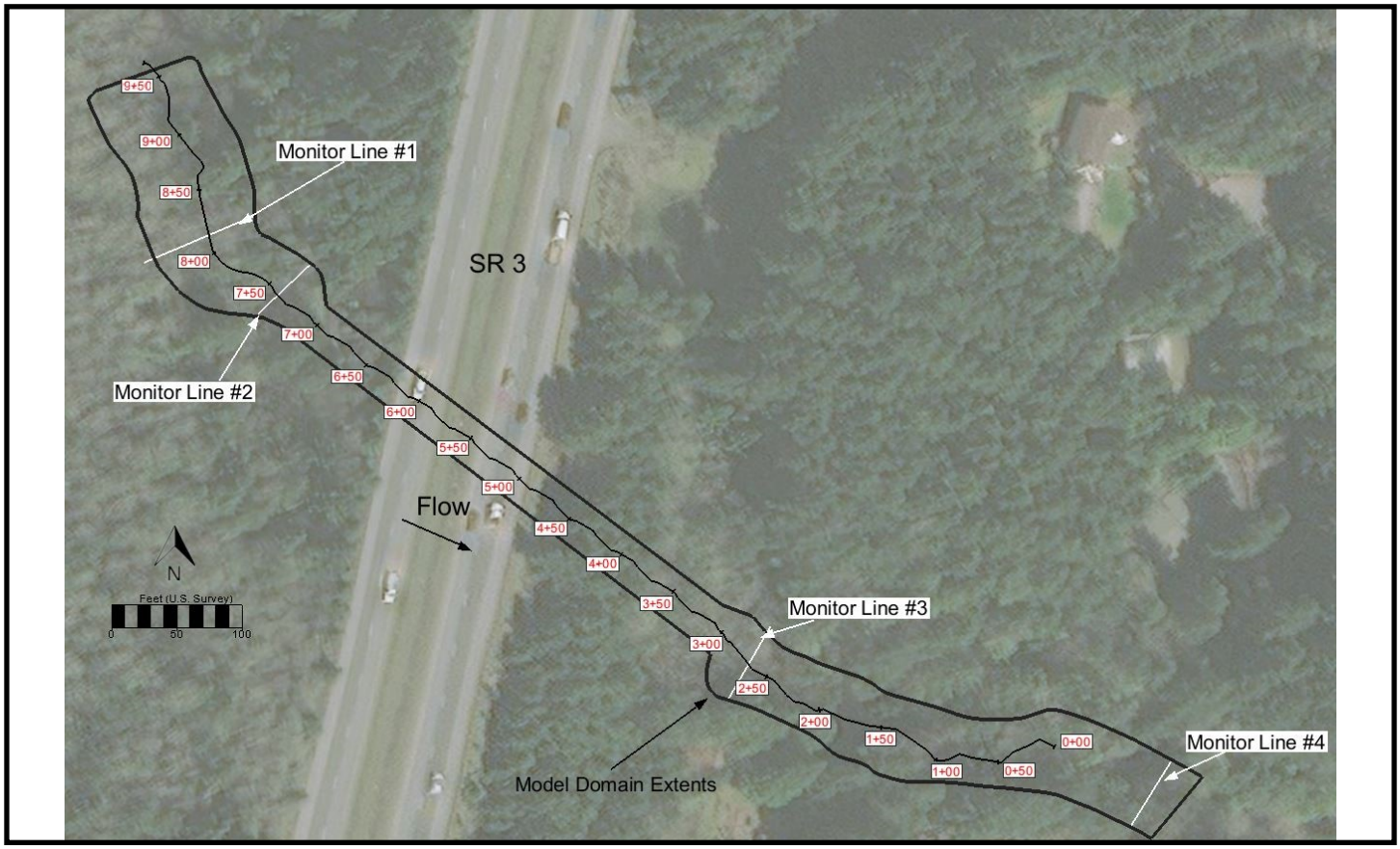
Appendix I: SRH-2D Model Stability and Continuity

DRAFT

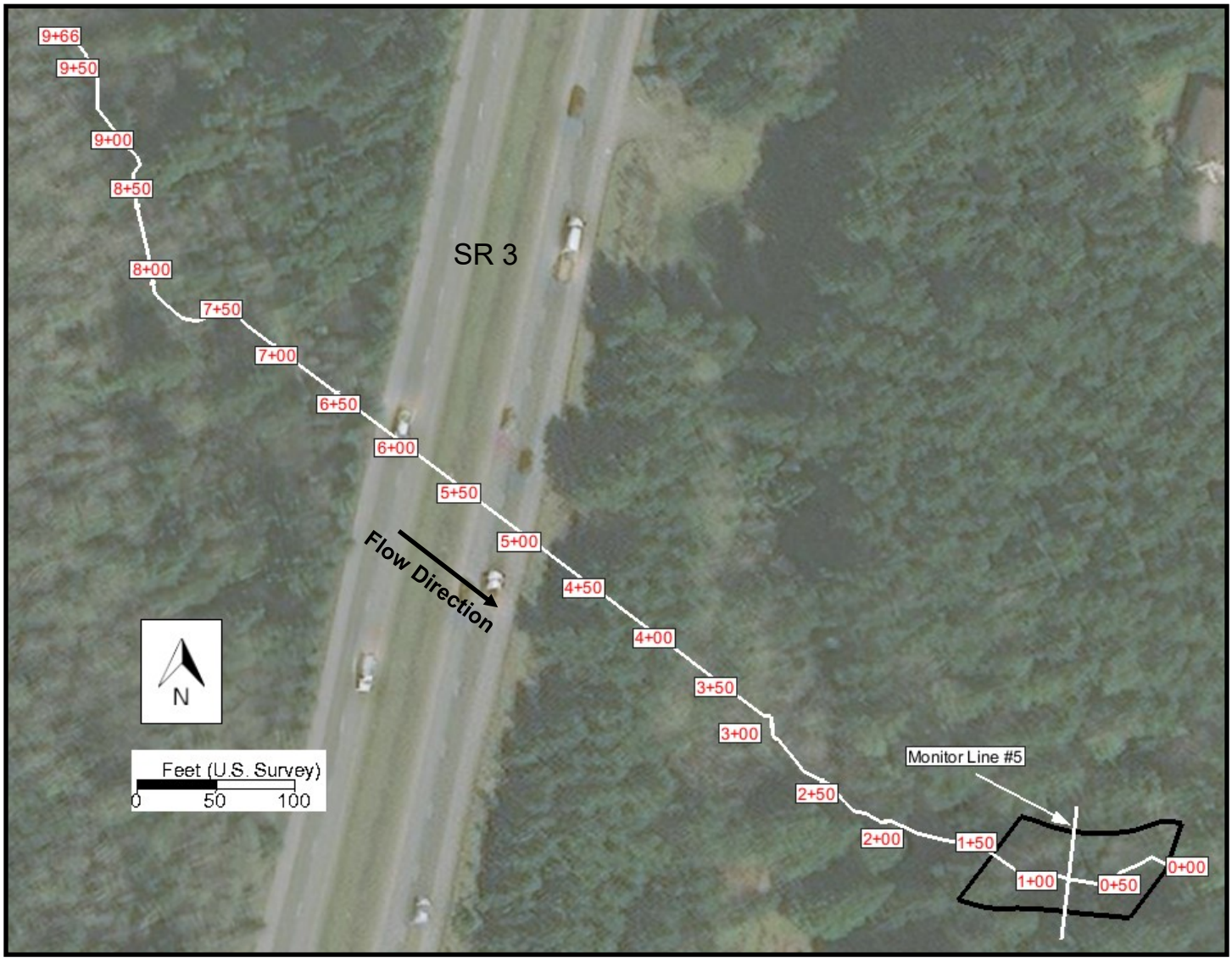
Existing Condition — Monitor Line Locations



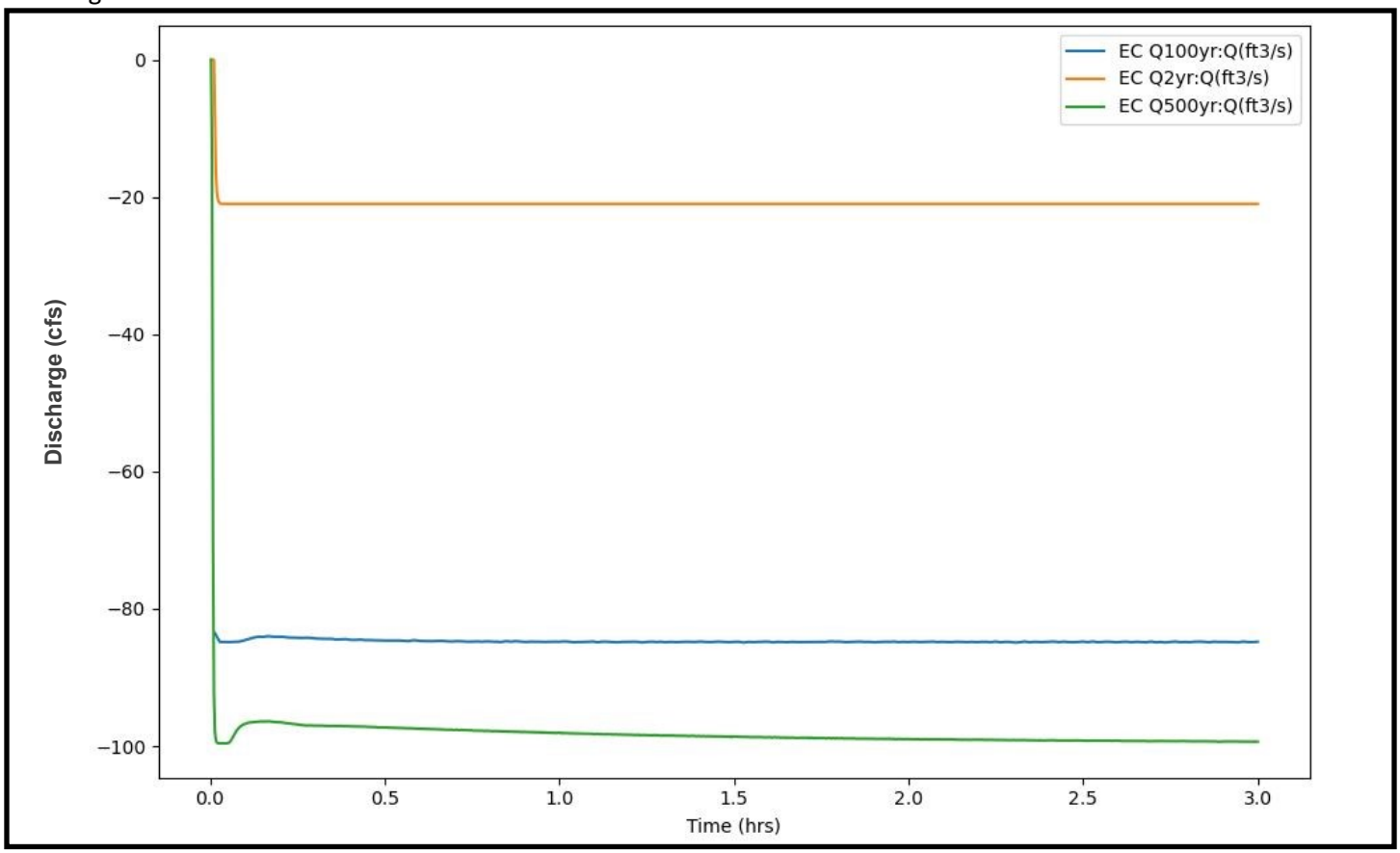
Proposed Condition —Monitor Line Locations



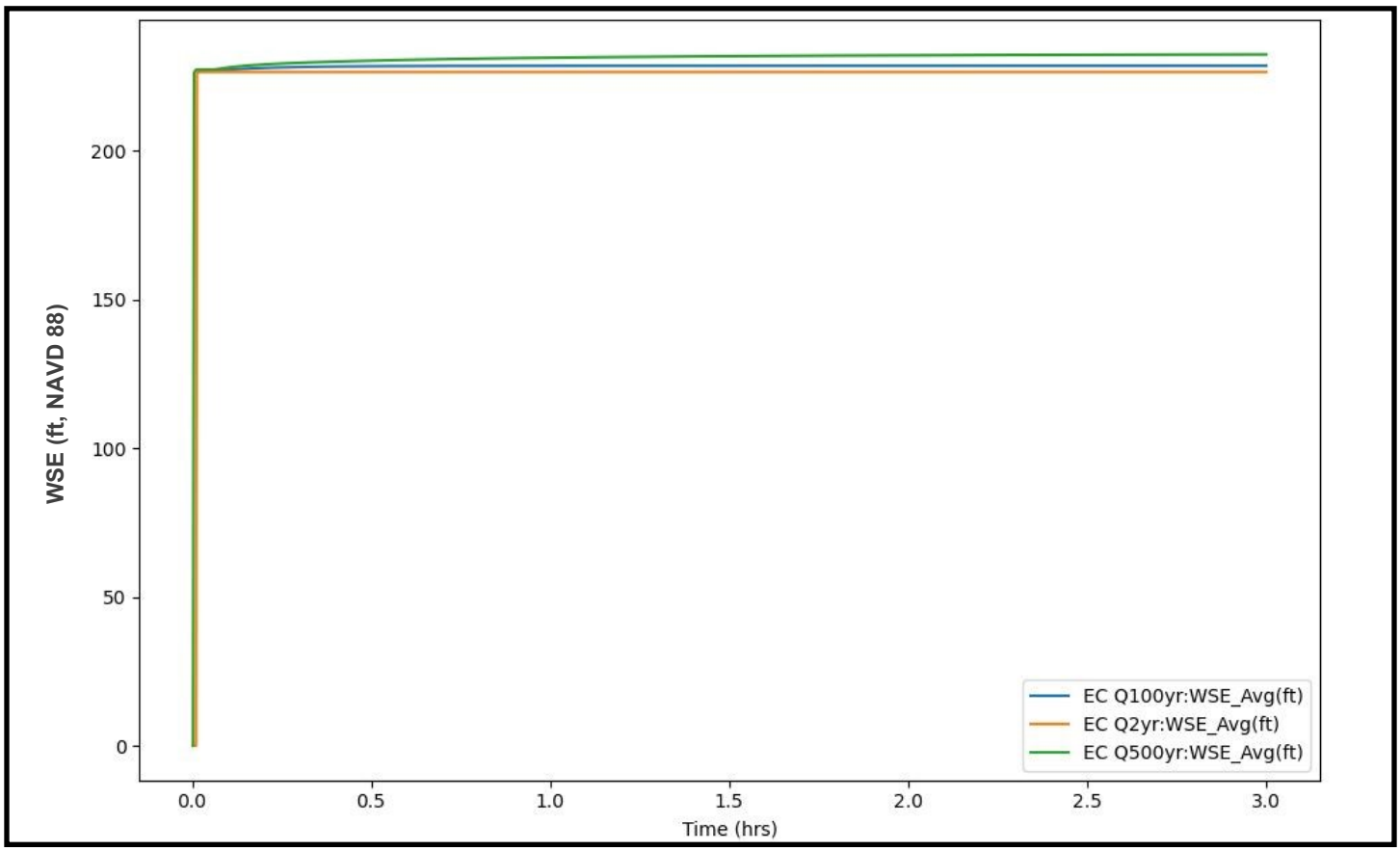
Existing Reference Reach — Monitor Line Locations



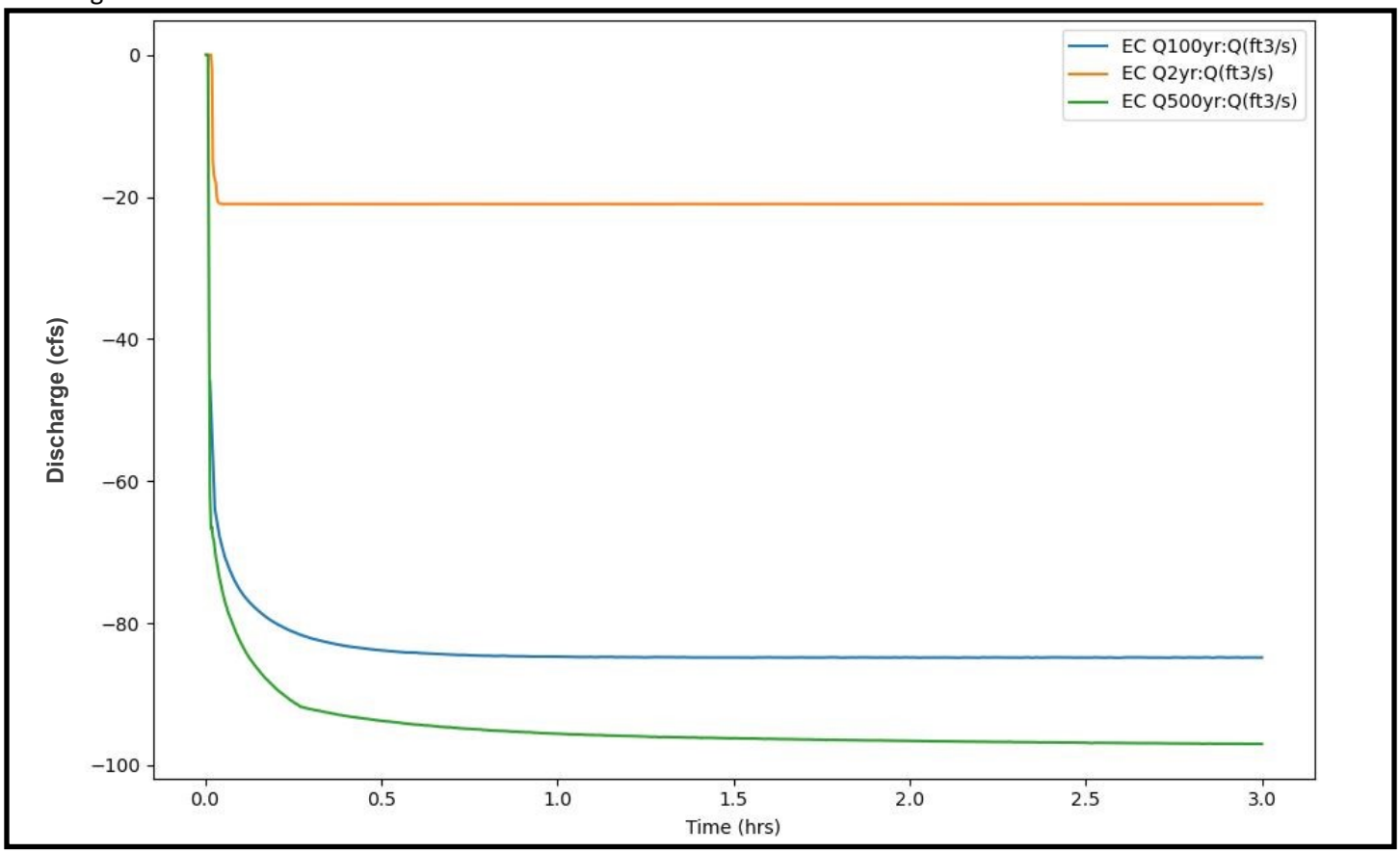
Existing Condition — Monitor Line 1 Flow vs. Time Plot



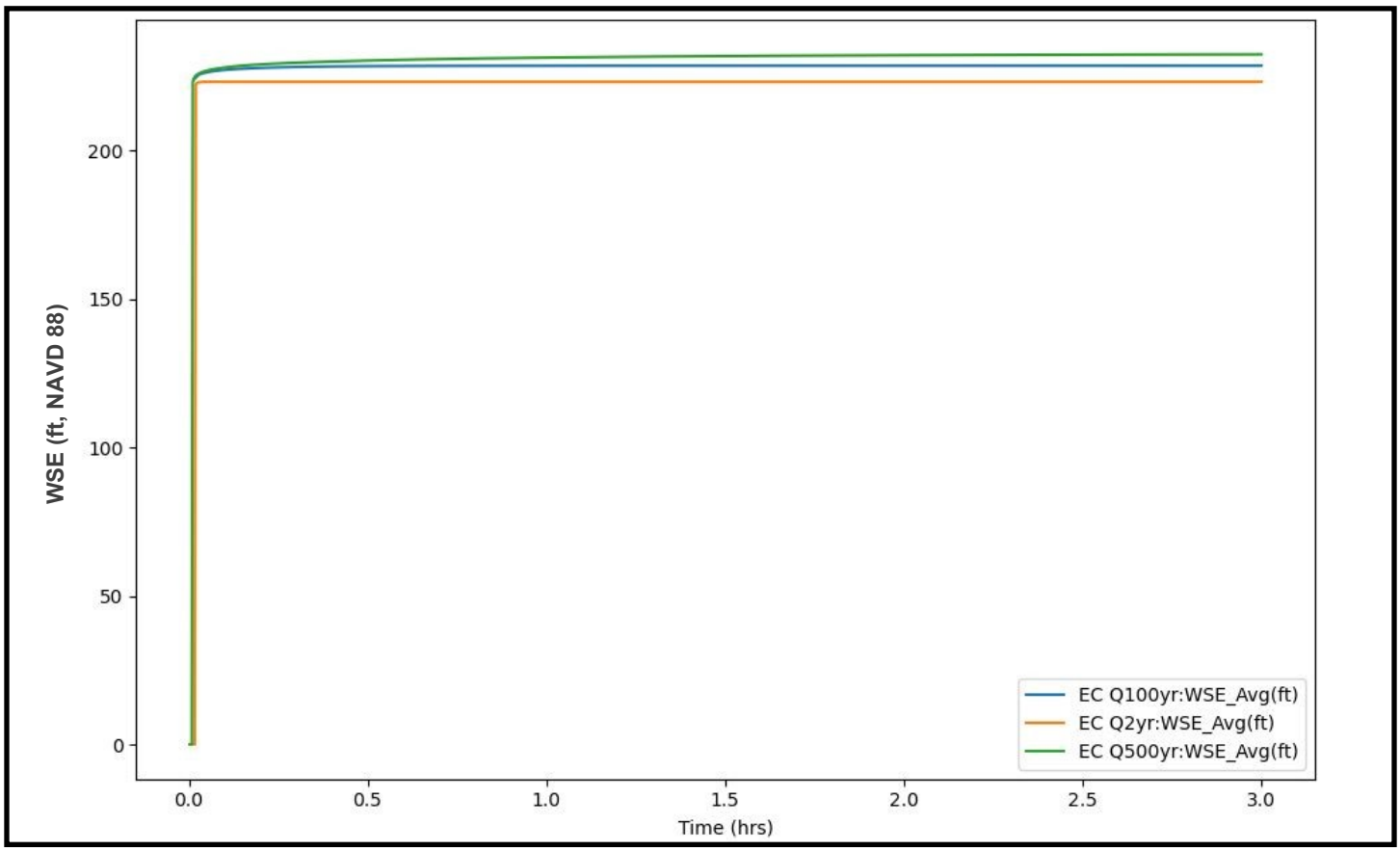
Existing Condition —Monitor Line 1 WSE vs. Time Plot



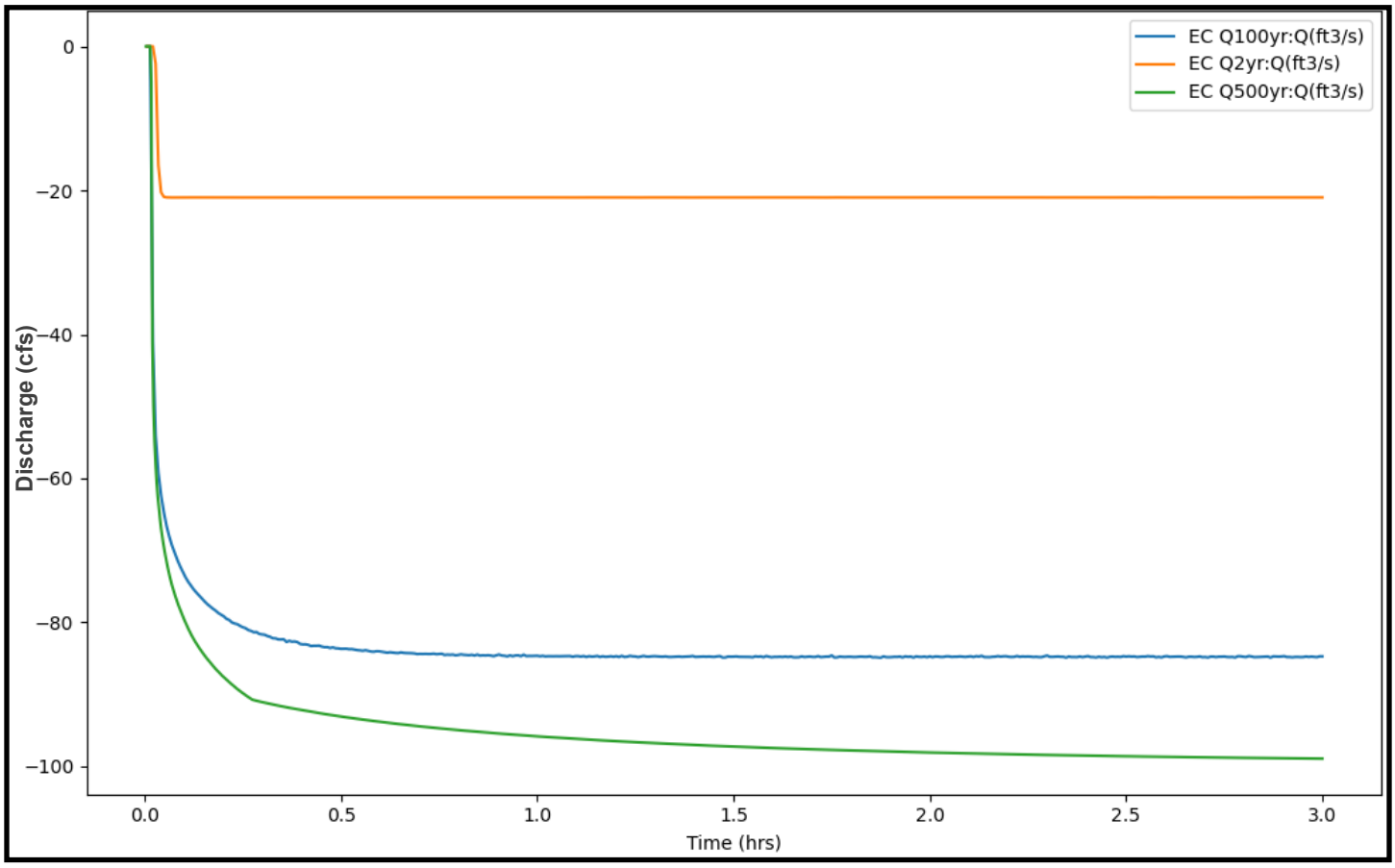
Existing Condition — Monitor Line 2 Flow vs. Time Plot



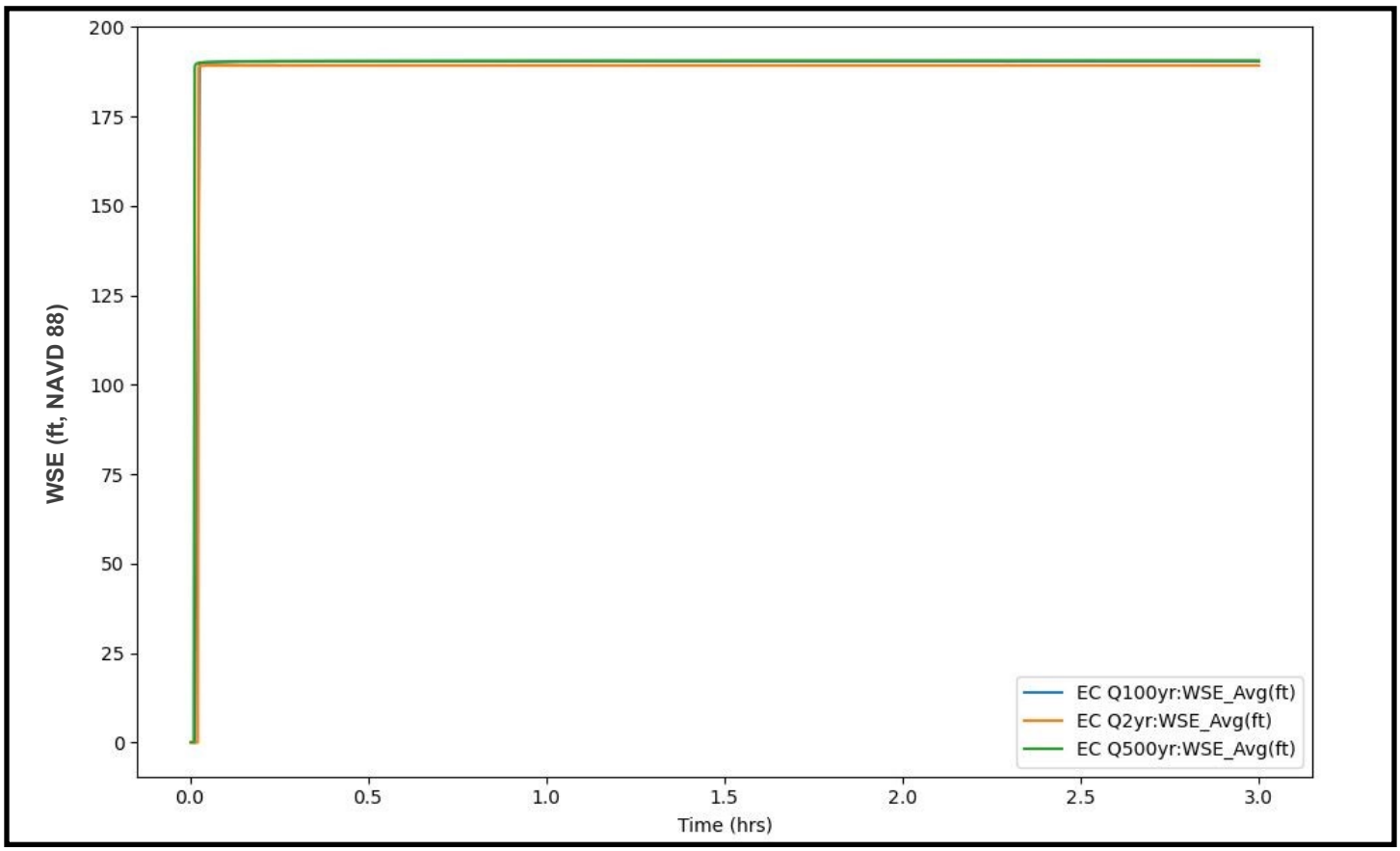
Existing Condition —Monitor Line 2 WSE vs. Time Plot



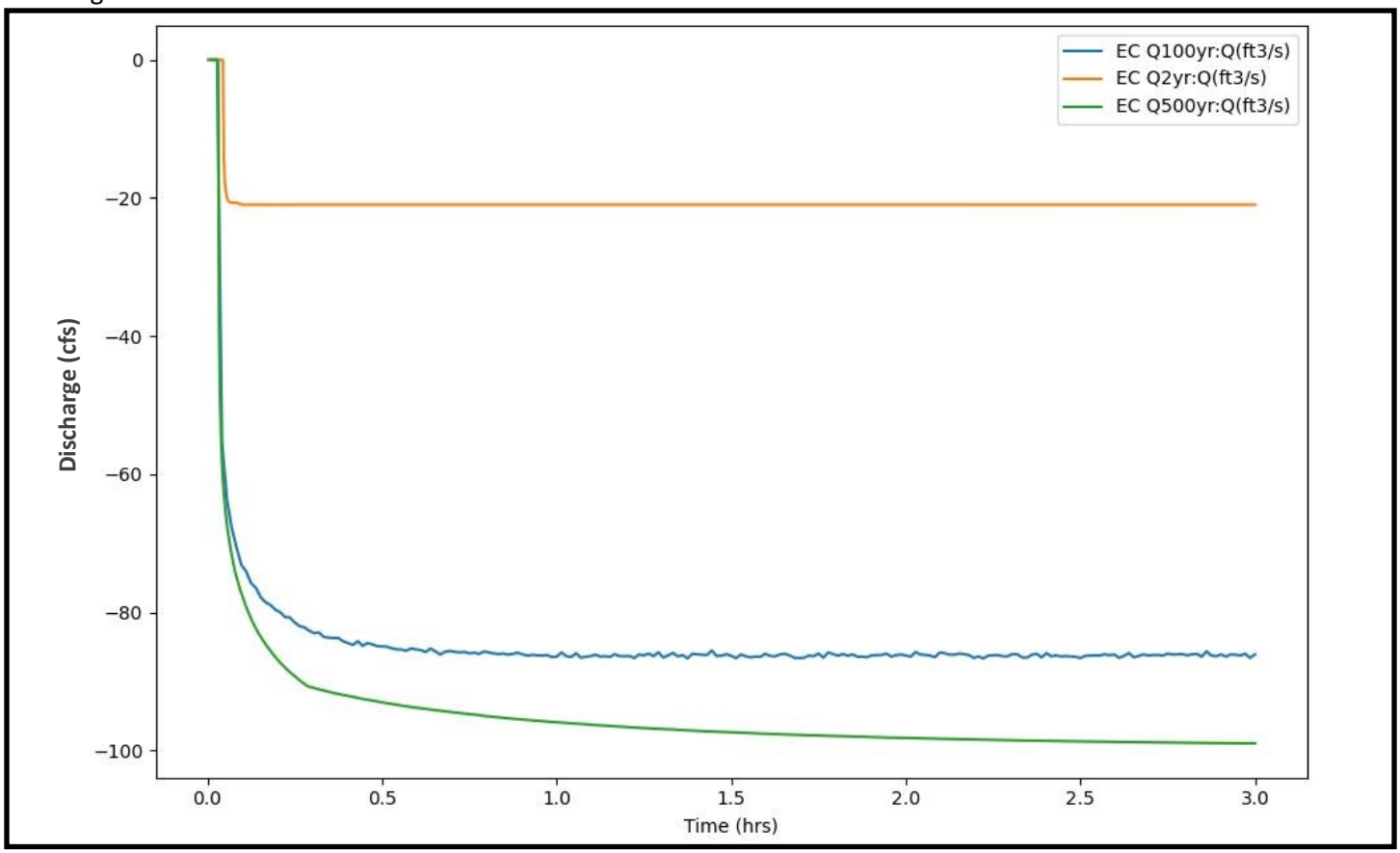
Existing Condition — Monitor Line 3 Flow vs. Time Plot



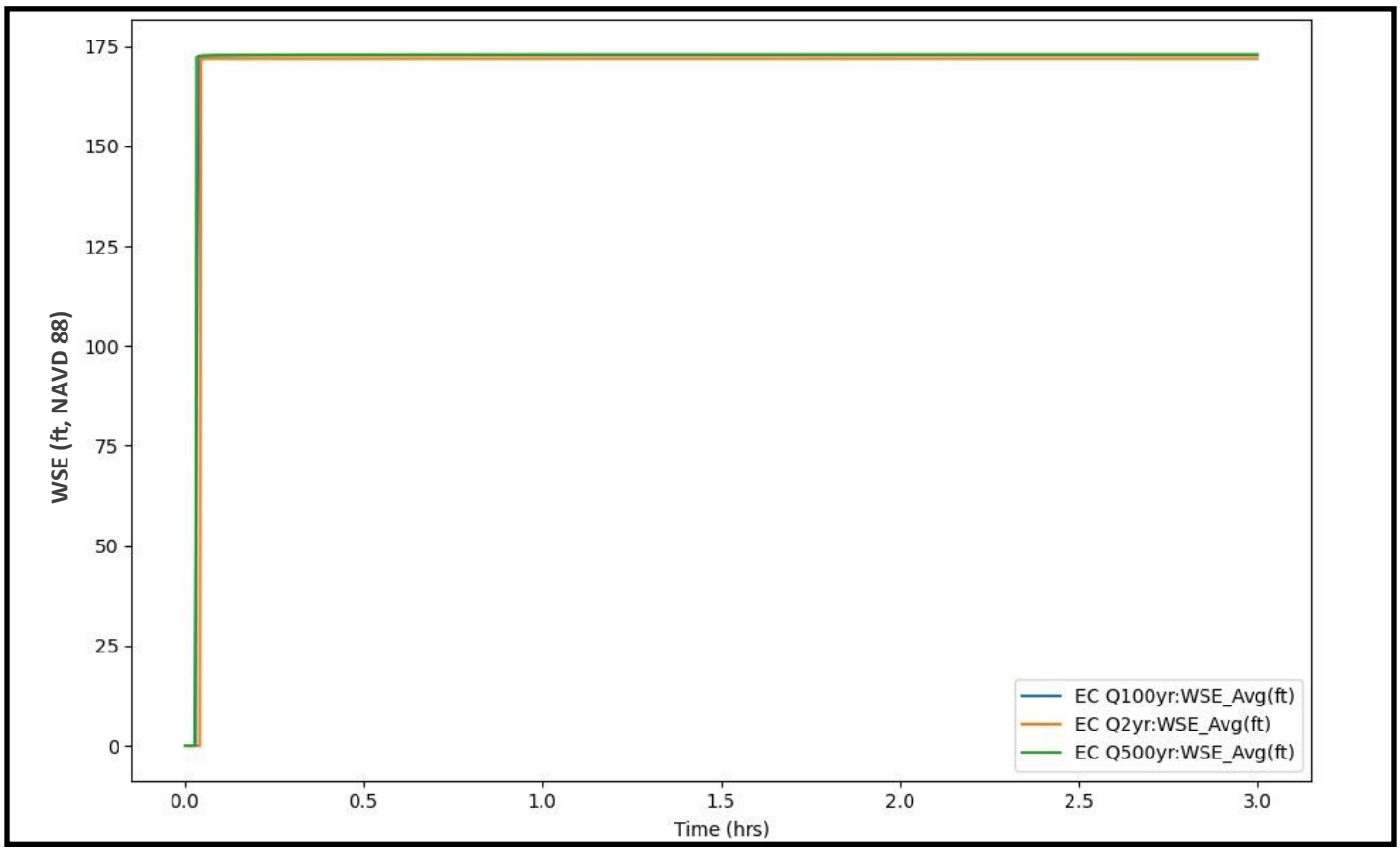
Existing Condition —Monitor Line 3 WSE vs. Time Plot



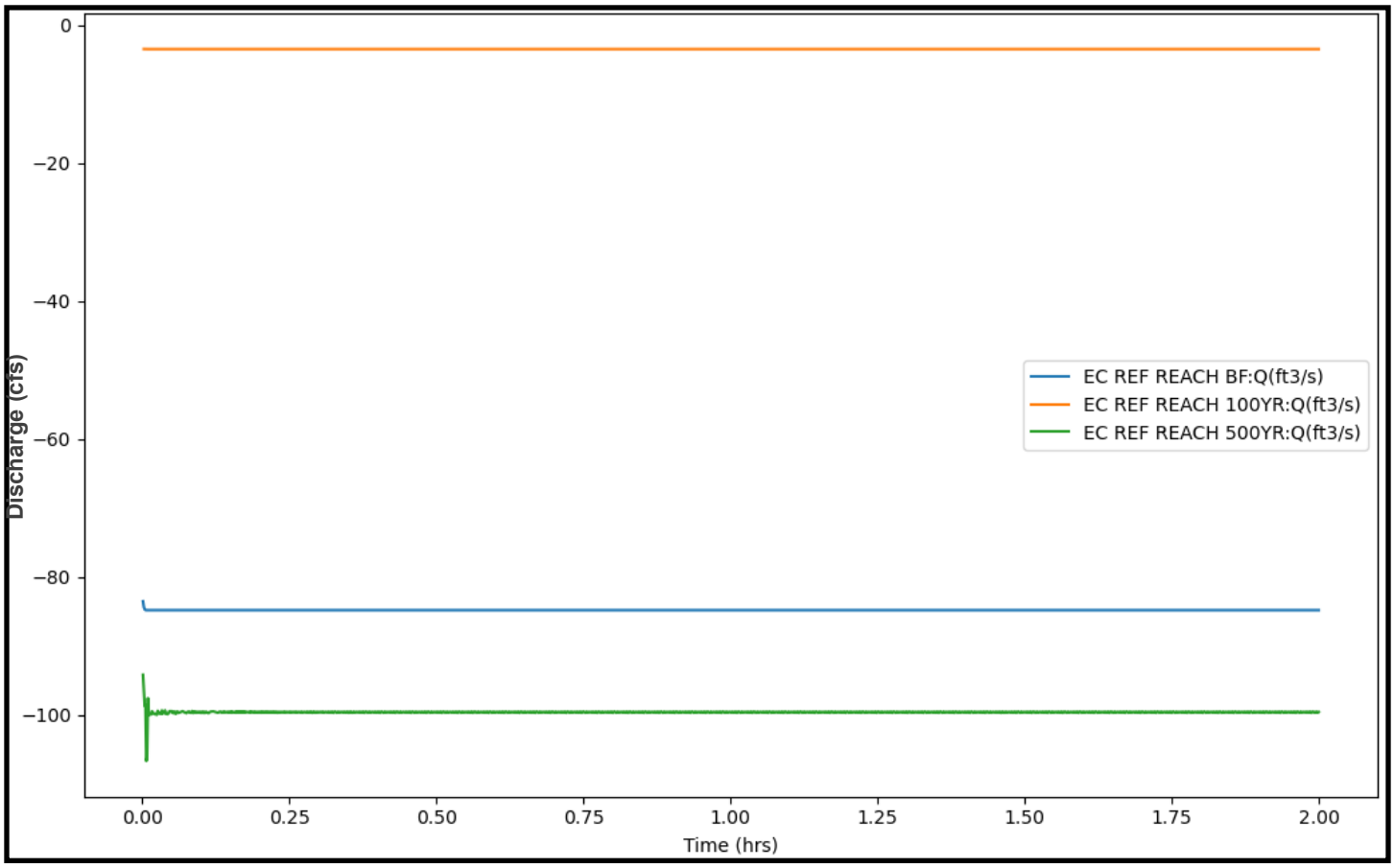
Existing Condition — Monitor Line 4 Flow vs. Time Plot



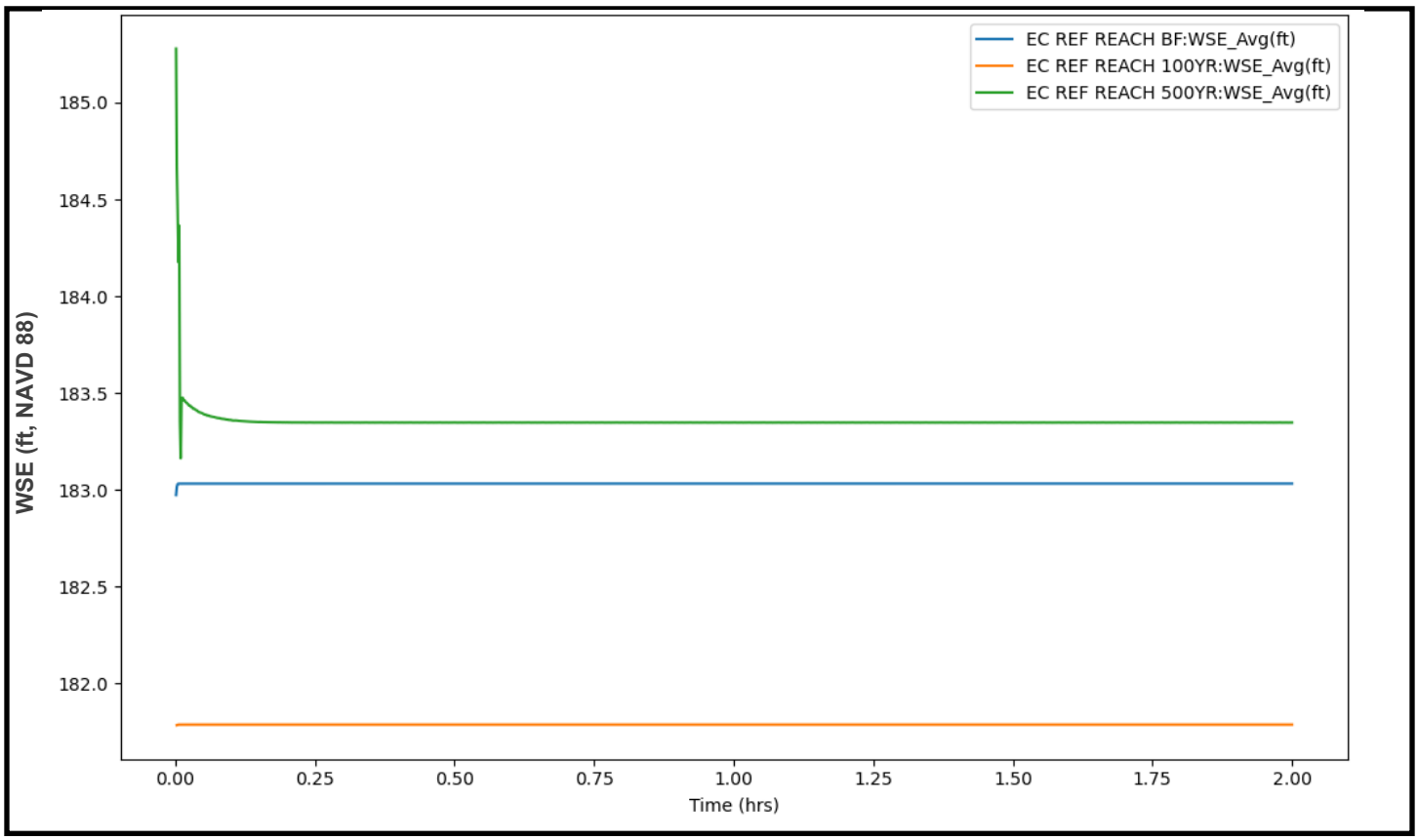
Existing Condition —Monitor Line 4 WSE vs. Time Plot



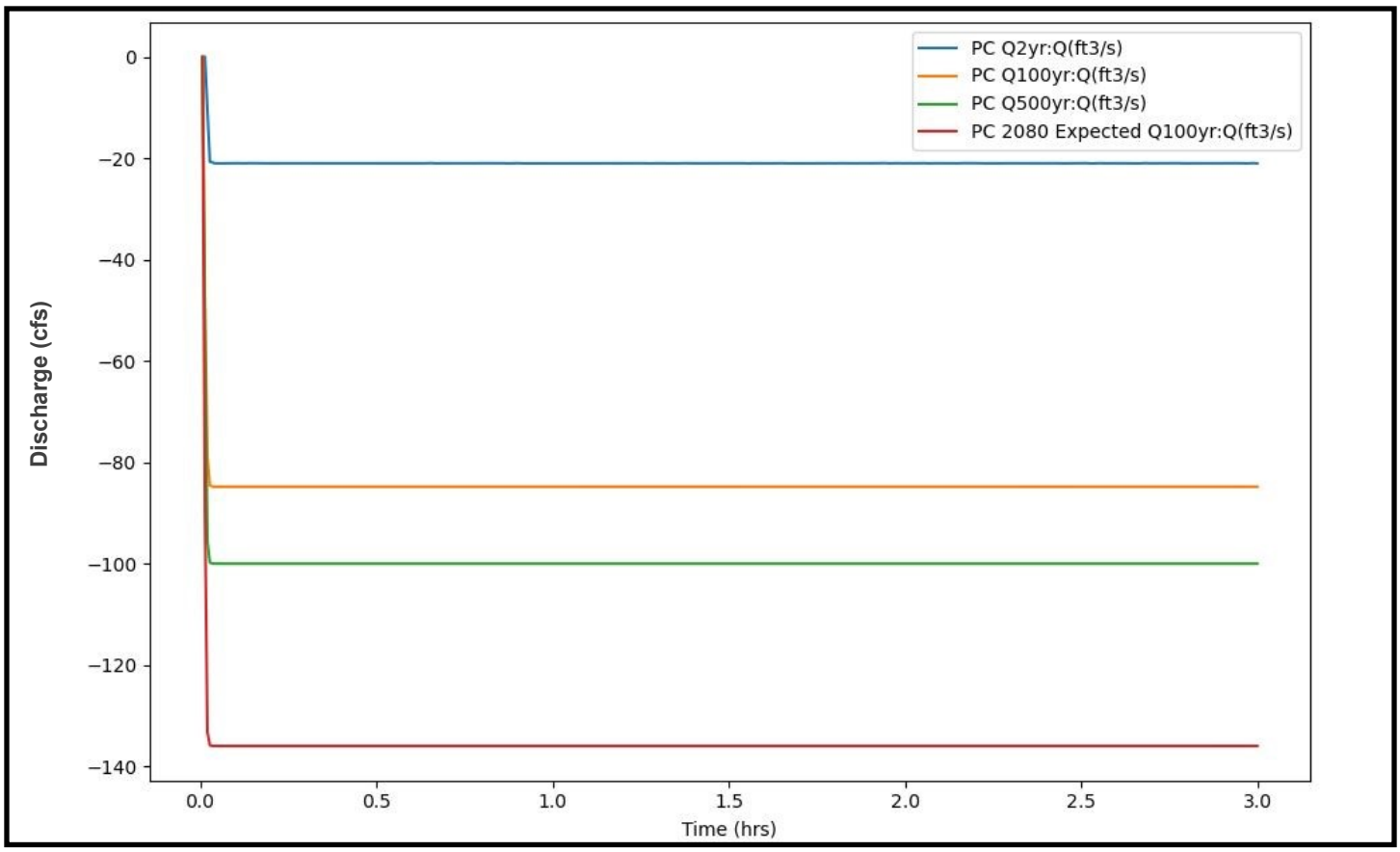
Existing Reference Reach — Monitor Line 5 Flow vs. Time Plot



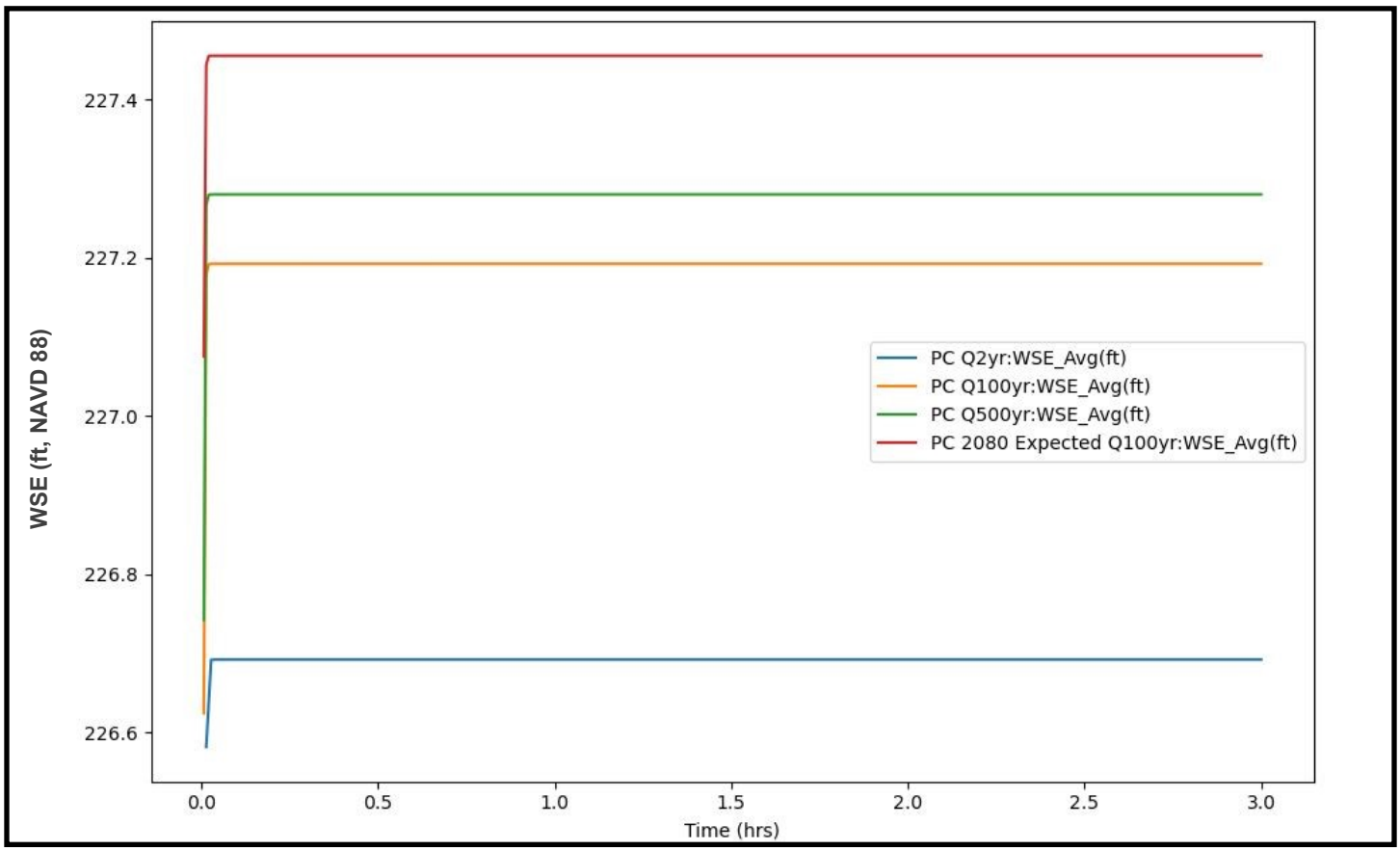
Existing Reference Reach —Monitor Line 5 WSE vs. Time Plot



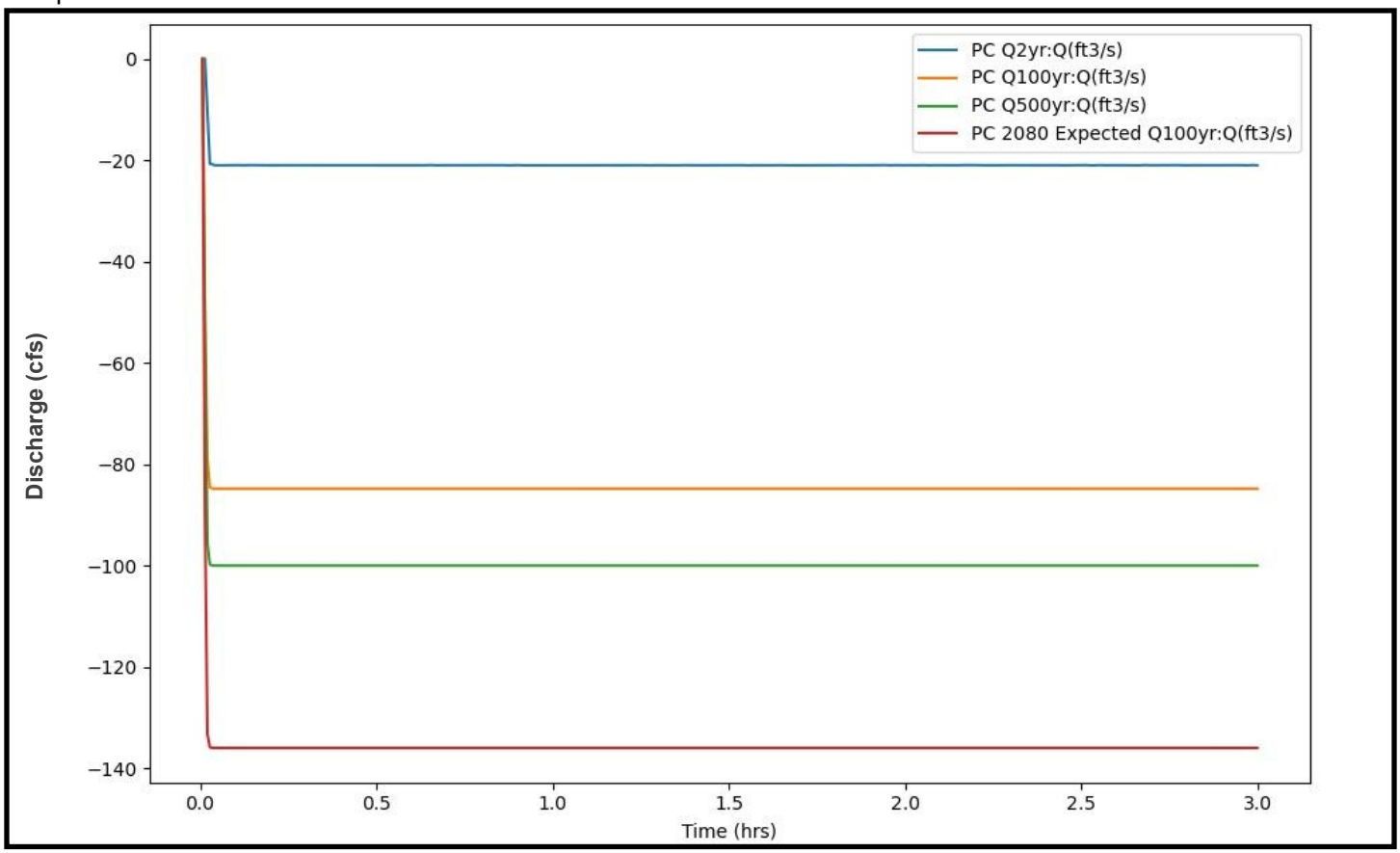
Proposed Condition — Monitor Line 1 Flow vs. Time Plot



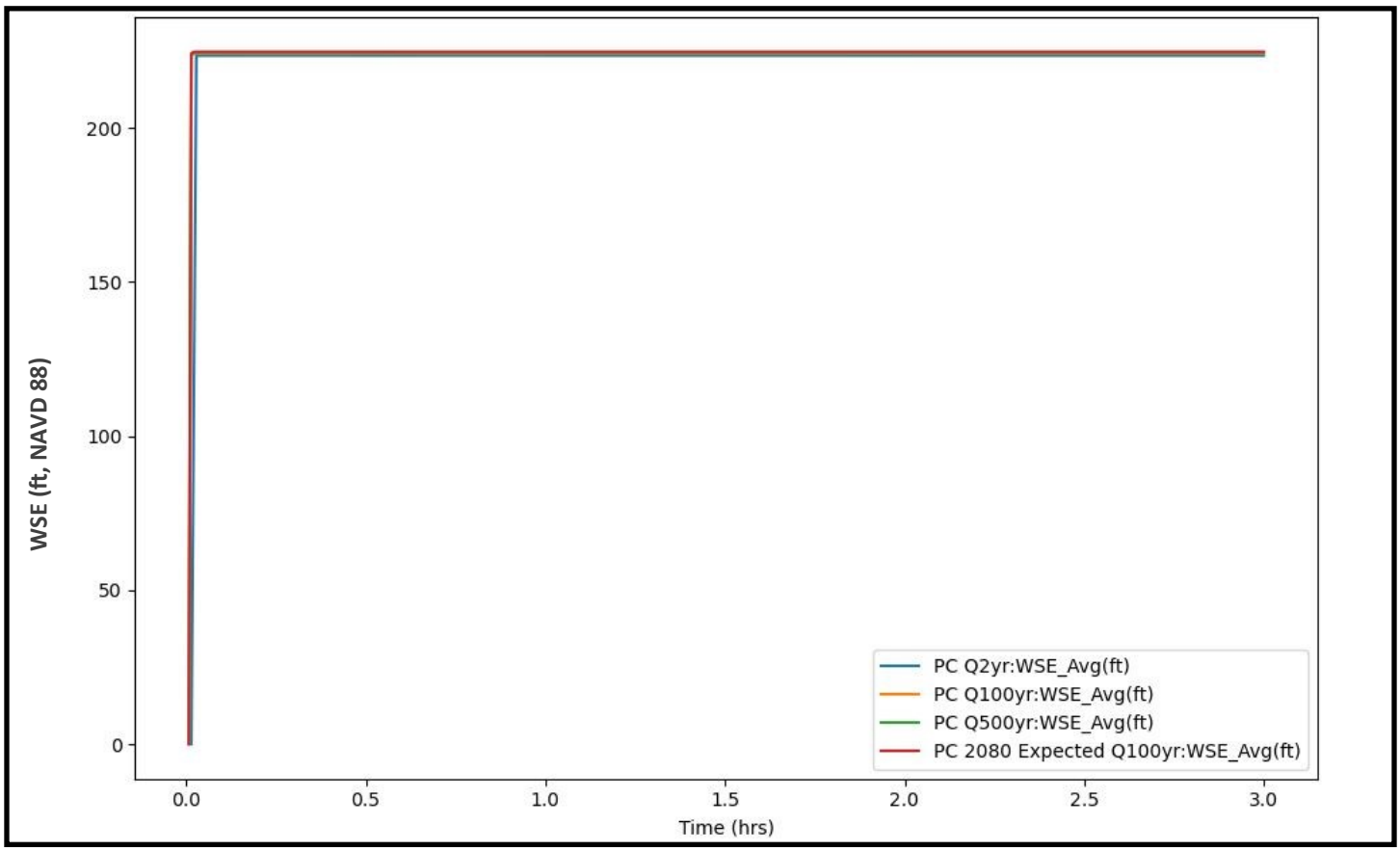
Proposed Condition —Monitor Line 1 WSE vs. Time Plot



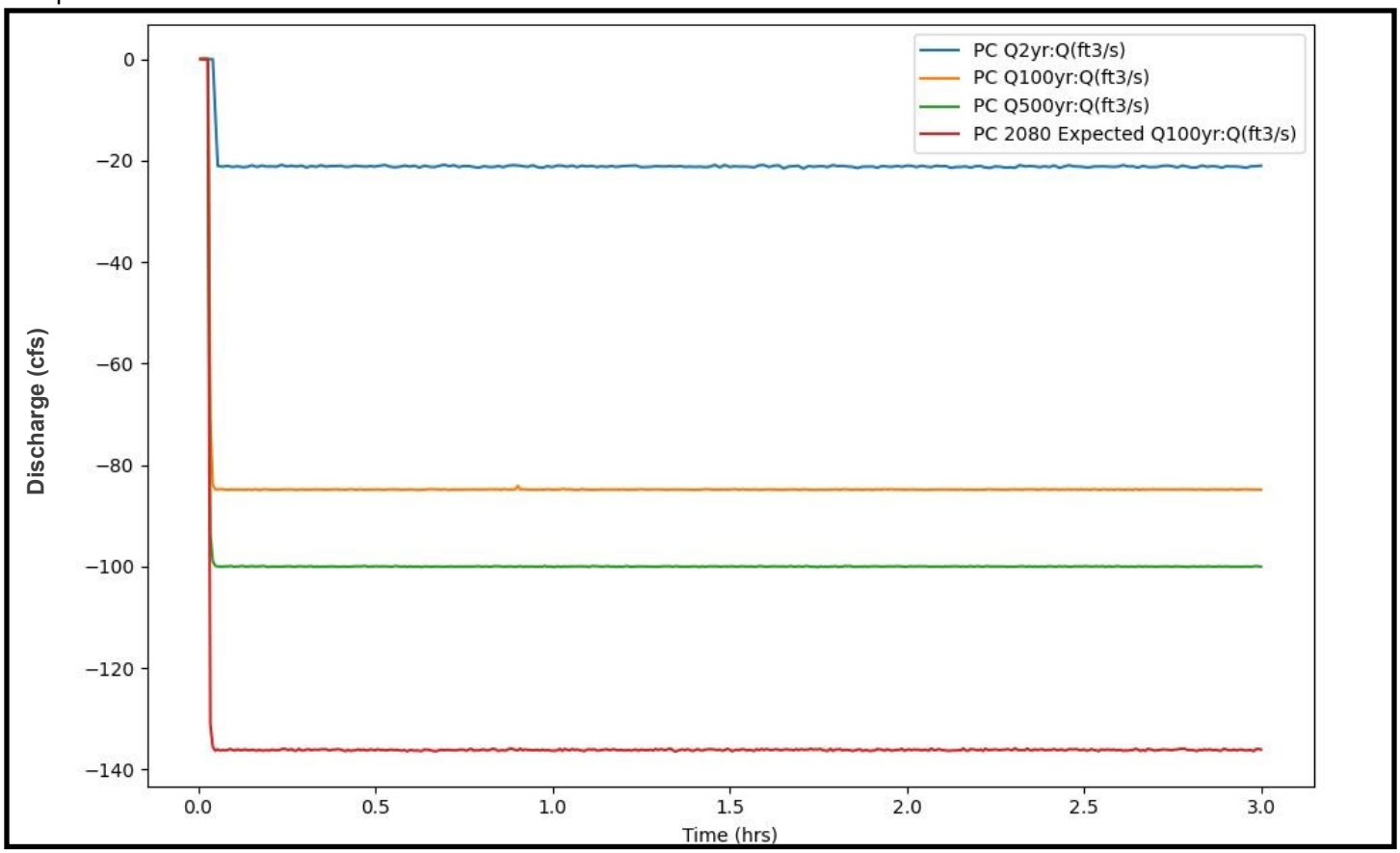
Proposed Condition — Monitor Line 2 Flow vs. Time Plot



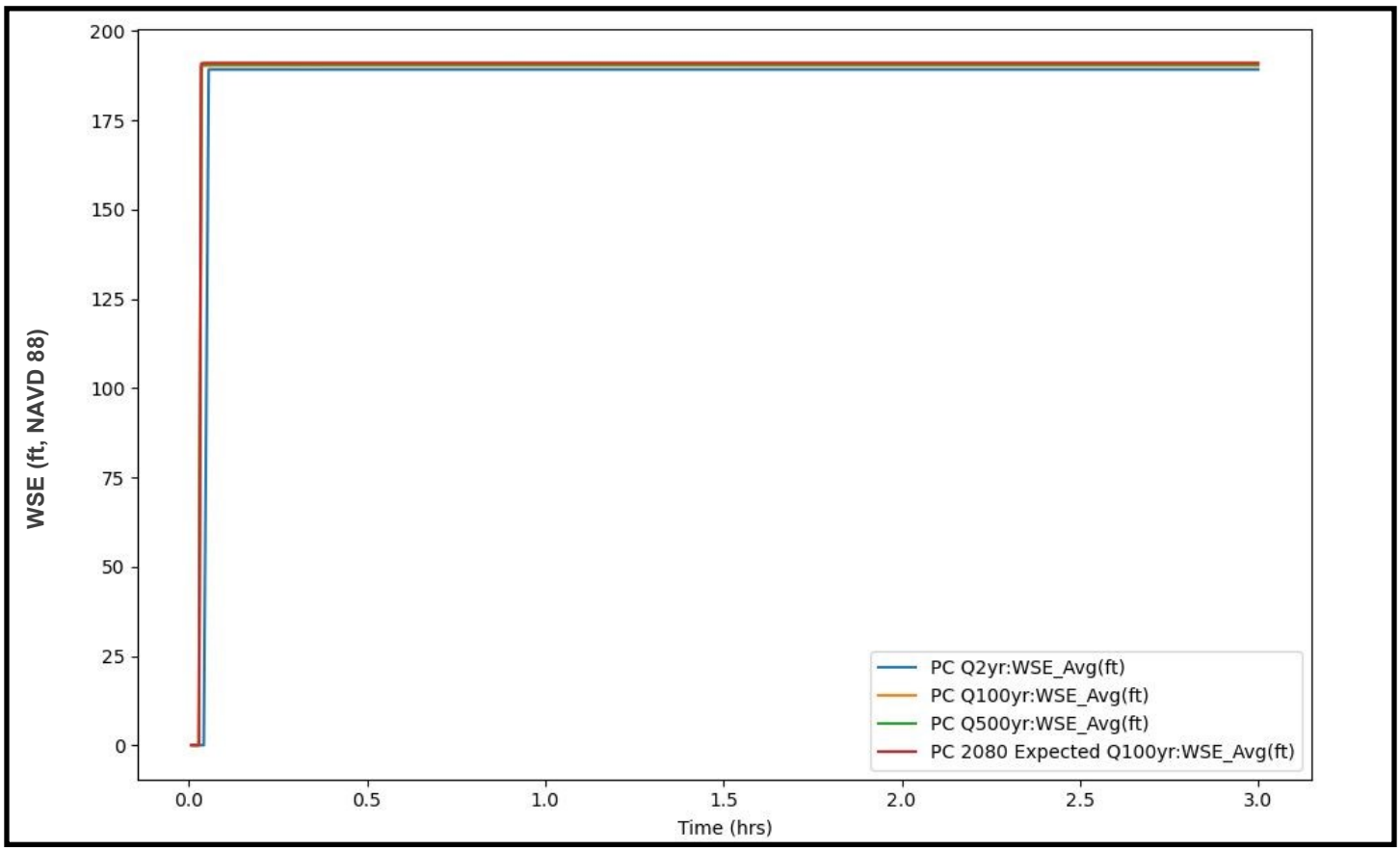
Proposed Condition —Monitor Line 2 WSE vs. Time Plot



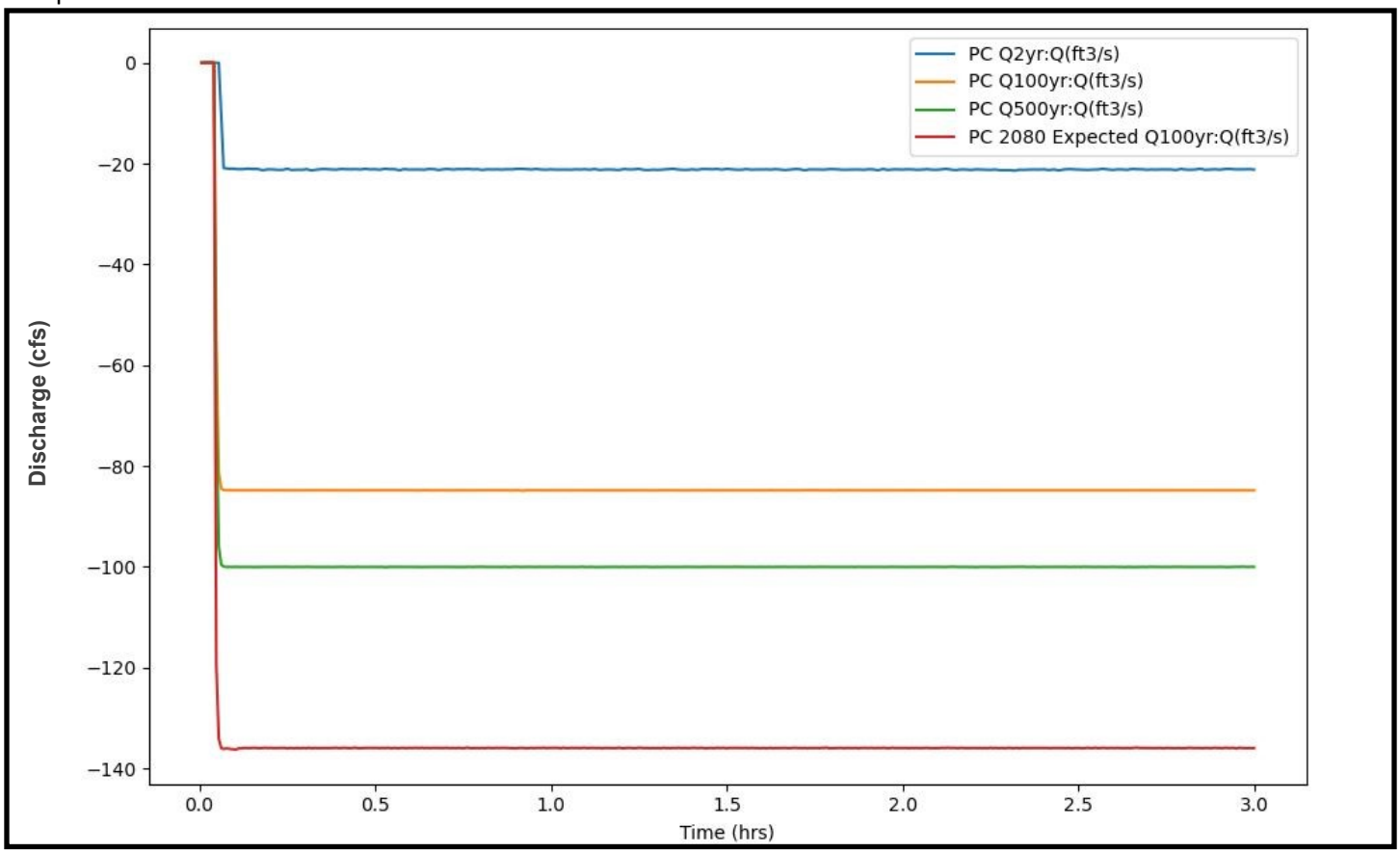
Proposed Condition — Monitor Line 3 Flow vs. Time Plot



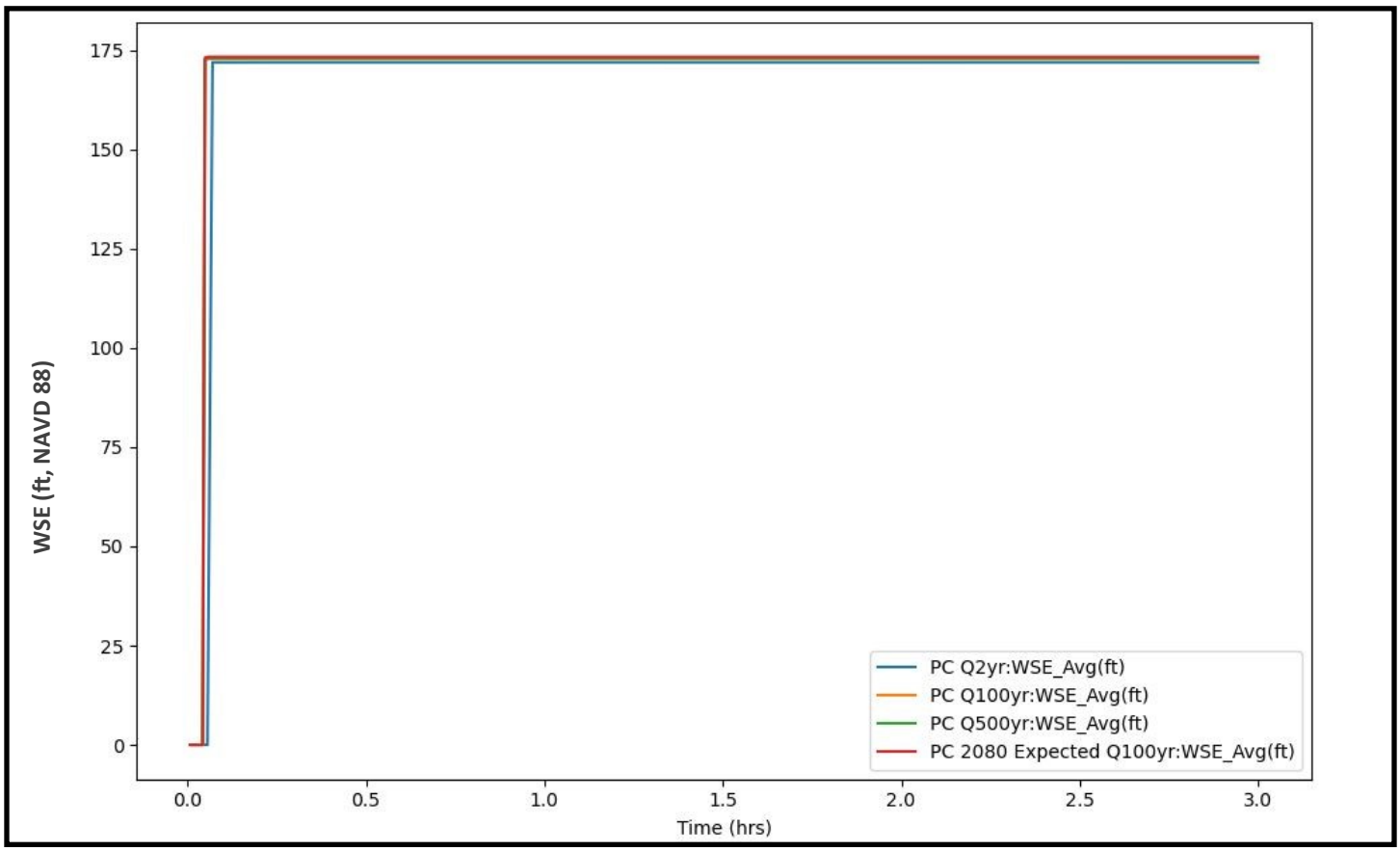
Proposed Condition —Monitor Line 3 WSE vs. Time Plot



Proposed Condition — Monitor Line 4 Flow vs. Time Plot



Proposed Condition —Monitor Line 4 WSE vs. Time Plot



Appendix J: Reach Assessment

There is no reach assessment for SF Johnson Creek at SR 3 MP 50.85.

DRAFT

Appendix K: Scour Calculations

DRAFT

Hydraulic Analysis Report

Project Data

Project Title: SR 3 MP 50.85 SF Johnson Creek to Johnson Creek

Designer: Jordan Laundry, EIT; Tim Bedford, PE

Project Date: Wednesday, October 12, 2022

Project Units: U.S. Customary Units

Notes: Proposed Conditions (PC) 2-, 100-, 500-, and 2080 100-year MRIs

Bridge Scour Analysis: 2yr

Notes:

Scenario: PC_2yr

Contraction Scour Summary

Contraction & Long Term Scour is applied method due to greater scour.

Applied Contraction Scour Depth 0.04 ft

Contraction & Long Term Scour is applied method due to greater scour.

Pressure Scour Depth 0.04 ft

Clear Water Contraction Scour Depth 0.04 ft

Live Bed Contraction Scour Depth 0.73 ft

Applied Contraction Scour Elevation with LTD 0.73 ft

Main Channel Contraction Scour

Computation Type: Clear-Water and Live-Bed Scour

Input Parameters

Average Depth Upstream of Contraction: 0.82 ft

D50: 20.330160 mm

Average Velocity Upstream: 1.23 ft/s

Results of Scour Condition

Critical velocity above which bed material of size D and smaller will be transported: 4.38 ft/s

Contraction Scour Condition: Clear-Water

Live Bed and/or Clear Water Input Parameters

Flow in Contracted Section: 5.87 cfs

Bottom Width in Contracted Section: 4.11 ft

Depth Prior to Scour in Contracted Section: 0.31 ft

Temperature of Water: 60.00 ºF

Slope of Energy Grade Line at Approach Section: 0.1324 ft/ft

Flow in Contracted Section: 5.87 cfs

Flow Upstream that is Transporting Sediment: 5.51 cfs

Width in Contracted Section: 4.11 ft

Width Upstream that is Transporting Sediment: 5.45 ft

Depth Prior to Scour in Contracted Section: 0.31 ft

Unit Weight of Water: 62.40 lb/ft^3

Unit Weight of Sediment: 165.00 lb/ft^3

Results of Clear Water Method

Diameter of the smallest nontransportable particle in the bed material: 25.412700 mm

Average Depth in Contracted Section after Scour: 0.34 ft

Scour Depth: 0.04 ft

Results of Live Bed Method

Shear Velocity: 1.87 ft/s

Fall Velocity: 1.64 ft/s

Average Depth in Contracted Section after Scour: 1.04 ft

Scour Depth for Live Bed: 0.73 ft

Shear Applied to Bed by Live-Bed Scour: 0.0254 lb/ft^2

Shear Required for Movement of D50 Particle: 0.2669 lb/ft^2

Recommendations

Recommended Scour Depth: 0.04 ft

Left Bank Contraction Scour

Computation Type: Clear-Water or Live-Bed Scour

Input Parameters

Average Depth Upstream of Contraction: 0.00 ft

D50: 0.000000 mm

Average Velocity Upstream: 0.00 ft/s

Results of Scour Condition

Critical velocity above which bed material of size D and smaller will be transported: 0.00 ft/s

Contraction Scour Condition: Live-Bed

Live Bed and/or Clear Water Input Parameters

Temperature of Water: 60.00 ºF

Slope of Energy Grade Line at Approach Section: 0.1324 ft/ft

Flow in Contracted Section: 0.00 cfs

Flow Upstream that is Transporting Sediment: 0.00 cfs

Width in Contracted Section: 0.00 ft

Width Upstream that is Transporting Sediment: 0.32 ft

Depth Prior to Scour in Contracted Section: 0.00 ft

Unit Weight of Water: 62.40 lb/ft^3

Unit Weight of Sediment: 165.00 lb/ft^3

Right Bank Contraction Scour

Computation Type: Clear-Water or Live-Bed Scour

Input Parameters

Average Depth Upstream of Contraction: 0.00 ft

D50: 0.000000 mm

Average Velocity Upstream: 0.00 ft/s

Results of Scour Condition

Critical velocity above which bed material of size D and smaller will be transported: 0.00 ft/s

Contraction Scour Condition: Live-Bed

Live Bed and/or Clear Water Input Parameters

Temperature of Water: 60.00 ºF

Slope of Energy Grade Line at Approach Section: 0.1324 ft/ft

Flow in Contracted Section: 0.22 cfs

Flow Upstream that is Transporting Sediment: 0.00 cfs

Width in Contracted Section: 0.64 ft

Width Upstream that is Transporting Sediment: 0.00 ft

Depth Prior to Scour in Contracted Section: 0.25 ft

Unit Weight of Water: 62.40 lb/ft^3

Unit Weight of Sediment: 165.00 lb/ft^3

Bridge Scour Analysis:100yr

Notes:

Scenario: PC_Q100_04May (SRH-2D)

Contraction Scour Summary

Contraction & Long Term Scour is applied method due to greater scour.

Applied Contraction Scour Depth 0.56 ft

Contraction & Long Term Scour is applied method due to greater scour.

Pressure Scour Depth 0.56 ft

Live Bed Contraction Scour Depth 0.56 ft

Applied Contraction Scour Elevation with LTD 0.56 ft

Local Scour at Abutments Summary

Left Abutment

Abutment Scour Method: NCHRP Method

Abutment Scour Depth 0.08 ft

Total Scour at Abutment 0.08 ft

Total Scour Elevation at Abutment 218.50 ft

Right Abutment

Abutment Scour Method: NCHRP Method

Abutment Scour Depth 0.08 ft

Total Scour at Abutment 0.08 ft

Total Scour Elevation at Abutment 218.50 ft

Main Channel Contraction Scour

Computation Type: Clear-Water or Live-Bed Scour

Input Parameters

Average Depth Upstream of Contraction: 1.48 ft

D50: 20.330160 mm

Average Velocity Upstream: 5.66 ft/s

Results of Scour Condition

Critical velocity above which bed material of size D and smaller will be transported: 4.84 ft/s

Contraction Scour Condition: Live-Bed

Live Bed and/or Clear Water Input Parameters

Temperature of Water: 60.00 ºF

Slope of Energy Grade Line at Approach Section: 0.1281 ft/ft

Flow in Contracted Section: 76.79 cfs

Flow Upstream that is Transporting Sediment: 52.08 cfs

Width in Contracted Section: 10.19 ft

Width Upstream that is Transporting Sediment: 6.20 ft

Depth Prior to Scour in Contracted Section: 0.95 ft

Unit Weight of Water: 62.40 lb/ft^3

Unit Weight of Sediment: 165.00 lb/ft^3

Results of Live Bed Method

Shear Velocity: 2.47 ft/s

Fall Velocity: 1.64 ft/s

Average Depth in Contracted Section after Scour: 1.51 ft

Scour Depth for Live Bed: 0.56 ft

Scour may be limited by armoring. Compute all methods to check.

Left Bank Contraction Scour

Computation Type: Clear-Water or Live-Bed Scour

Input Parameters

Average Depth Upstream of Contraction: 0.58 ft

D50: 0.000000 mm

Average Velocity Upstream: 2.64 ft/s

Results of Scour Condition

Critical velocity above which bed material of size D and smaller will be transported: 0.00 ft/s

Contraction Scour Condition: Live-Bed

Live Bed and/or Clear Water Input Parameters

Temperature of Water: 60.00 ºF

Slope of Energy Grade Line at Approach Section: 0.1281 ft/ft

Flow in Contracted Section: 3.13 cfs

Flow Upstream that is Transporting Sediment: 22.21 cfs

Width in Contracted Section: 2.99 ft

Width Upstream that is Transporting Sediment: 14.45 ft

Depth Prior to Scour in Contracted Section: 0.27 ft

Unit Weight of Water: 62.40 lb/ft^3

Unit Weight of Sediment: 165.00 lb/ft^3

Right Bank Contraction Scour

Computation Type: Clear-Water or Live-Bed Scour

Input Parameters

Average Depth Upstream of Contraction: 0.58 ft

D50: 0.000000 mm

Average Velocity Upstream: 2.21 ft/s

Results of Scour Condition

Critical velocity above which bed material of size D and smaller will be transported: 0.00 ft/s

Contraction Scour Condition: Live-Bed

Live Bed and/or Clear Water Input Parameters

Temperature of Water: 60.00 ºF

Slope of Energy Grade Line at Approach Section: 0.1281 ft/ft

Flow in Contracted Section: 4.89 cfs

Flow Upstream that is Transporting Sediment: 11.81 cfs

Width in Contracted Section: 2.76 ft

Width Upstream that is Transporting Sediment: 9.30 ft

Depth Prior to Scour in Contracted Section: 0.56 ft

Unit Weight of Water: 62.40 lb/ft^3

Unit Weight of Sediment: 165.00 lb/ft^3

Left Abutment Details

Abutment Scour

Computation Type: NCHRP

Input Parameters

NCHRP Method

Abutment Type: Vertical-wall abutment

Angle of Embankment to Flow: 84.88 Degrees

Centerline Length of Embankment: 0.00 ft

Projected Length of Embankment: 0.00 ft

Width of Flood Plain: 0.00 ft

Unit Discharge, Upstream in Main Channel (q1): 8.40 cfs

Unit Discharge in the Constricted Area (q2): 7.54 cfs/ft

D50: 20.330160 mm

Upstream Flow Depth: 1.48 ft

Flow Depth Prior to Scour: 1.47 ft

Result Parameters

q2/q1: 0.90

Average Velocity Upstream: 5.66 ft/s

Critical Velocity above which Bed Materal of Size D and Smaller will be Transported: 4.84 ft/s

Scour Condition: Live Bed

Embankment Length/Floodplain Width Ratio: 0.00

Scour Condition: a (Main Channel)

Amplification Factor: 1.20

Flow Depth including Contraction Scour: 1.55 ft

Maximum Flow Depth including Abutment Scour: 1.55 ft

Scour Hole Depth from NCHRP Method: 0.08 ft

Right Abutment Details

Abutment Scour

Computation Type: NCHRP

Input Parameters

NCHRP Method

Abutment Type: Vertical-wall abutment

Angle of Embankment to Flow: 95.12 Degrees

Centerline Length of Embankment: 0.00 ft

Projected Length of Embankment: 0.00 ft

Width of Flood Plain: 0.00 ft

Unit Discharge, Upstream in Main Channel (q1): 8.40 cfs

Unit Discharge in the Constricted Area (q2): 7.54 cfs/ft

D50: 20.330160 mm

Upstream Flow Depth: 1.48 ft

Flow Depth Prior to Scour: 1.47 ft

Result Parameters

q2/q1: 0.90

Average Velocity Upstream: 5.66 ft/s

Critical Velocity above which Bed Materal of Size D and Smaller will be Transported: 4.84 ft/s

Scour Condition: Live Bed

Embankment Length/Floodplain Width Ratio: 0.00

Scour Condition: a (Main Channel)

Amplification Factor: 1.20

Flow Depth including Contraction Scour: 1.55 ft

Maximum Flow Depth including Abutment Scour: 1.55 ft

Scour Hole Depth from NCHRP Method: 0.08 ft

Bridge Scour Analysis:500yr

Notes:

Scenario: PC_Q500

Contraction Scour Summary

Contraction & Long Term Scour is applied method due to greater scour.

Applied Contraction Scour Depth 0.55 ft

Contraction & Long Term Scour is applied method due to greater scour.

Pressure Scour Depth 0.55 ft

Clear Water Contraction Scour Depth 0.55 ft

Live Bed Contraction Scour Depth 0.66 ft

Applied Contraction Scour Elevation with LTD 0.66 ft

Local Scour at Abutments Summary

Left Abutment

Abutment Scour Method: NCHRP Method

Abutment Scour Depth 1.44 ft

Total Scour at Abutment 1.44 ft

Total Scour Elevation at Abutment 218.82 ft

Right Abutment

Abutment Scour Method: NCHRP Method

Abutment Scour Depth -0.14 ft

Total Scour at Abutment 0.00 ft

Total Scour Elevation at Abutment 218.82 ft

Main Channel Contraction Scour

Computation Type: Clear-Water and Live-Bed Scour

Input Parameters

Average Depth Upstream of Contraction: 1.47 ft

D50: 20.330160 mm

Average Velocity Upstream: 5.85 ft/s

Results of Scour Condition

Critical velocity above which bed material of size D and smaller will be transported: 4.83 ft/s

Contraction Scour Condition: Live-Bed

Live Bed and/or Clear Water Input Parameters

Temperature of Water: 60.00 ºF

Slope of Energy Grade Line at Approach Section: 0.0503 ft/ft

Flow in Contracted Section: 110.88 cfs

Flow Upstream that is Transporting Sediment: 62.45 cfs

Width in Contracted Section: 15.37 ft

Width Upstream that is Transporting Sediment: 7.24 ft

Depth Prior to Scour in Contracted Section: 0.83 ft

Unit Weight of Water: 62.40 lb/ft^3

Unit Weight of Sediment: 165.00 lb/ft^3

Results of Clear Water Method

Diameter of the smallest nontransportable particle in the bed material: 25.412700 mm

Average Depth in Contracted Section after Scour: 1.37 ft

Scour Depth: 0.55 ft

Results of Live Bed Method

Shear Velocity: 1.54 ft/s

Fall Velocity: 1.64 ft/s

Average Depth in Contracted Section after Scour: 1.49 ft

Scour Depth for Live Bed: 0.66 ft

Shear Applied to Bed by Live-Bed Scour: 0.3553 lb/ft^2

Shear Required for Movement of D50 Particle: 0.2669 lb/ft^2

Recommendations

Recommended Scour Depth: 0.55 ft

Left Bank Contraction Scour

Computation Type: Clear-Water or Live-Bed Scour

Input Parameters

Average Depth Upstream of Contraction: 0.68 ft

D50: 0.000000 mm

Average Velocity Upstream: 2.90 ft/s

Results of Scour Condition

Critical velocity above which bed material of size D and smaller will be transported: 0.00 ft/s

Contraction Scour Condition: Live-Bed

Live Bed and/or Clear Water Input Parameters

Temperature of Water: 60.00 ºF

Slope of Energy Grade Line at Approach Section: 0.0503 ft/ft

Flow in Contracted Section: 0.61 cfs

Flow Upstream that is Transporting Sediment: 26.74 cfs

Width in Contracted Section: 1.62 ft

Width Upstream that is Transporting Sediment: 13.60 ft

Depth Prior to Scour in Contracted Section: 0.09 ft

Unit Weight of Water: 62.40 lb/ft^3

Unit Weight of Sediment: 165.00 lb/ft^3

Right Bank Contraction Scour

Computation Type: Clear-Water or Live-Bed Scour

Input Parameters

Average Depth Upstream of Contraction: 0.66 ft

D50: 0.000000 mm

Average Velocity Upstream: 2.19 ft/s

Results of Scour Condition

Critical velocity above which bed material of size D and smaller will be transported: 0.00 ft/s

Contraction Scour Condition: Live-Bed

Live Bed and/or Clear Water Input Parameters

Temperature of Water: 60.00 ºF

Slope of Energy Grade Line at Approach Section: 0.0503 ft/ft

Flow in Contracted Section: 2.12 cfs

Flow Upstream that is Transporting Sediment: 13.23 cfs

Width in Contracted Section: 1.53 ft

Width Upstream that is Transporting Sediment: 9.11 ft

Depth Prior to Scour in Contracted Section: 0.40 ft

Unit Weight of Water: 62.40 lb/ft^3

Unit Weight of Sediment: 165.00 lb/ft^3

Left Abutment Details

Abutment Scour

Computation Type: NCHRP

Input Parameters

NCHRP Method

Abutment Type: Spill-through abutment

Angle of Embankment to Flow: 89.54 Degrees

Centerline Length of Embankment: 0.00 ft

Projected Length of Embankment: 0.00 ft

Width of Flood Plain: 0.00 ft

Unit Discharge, Upstream in Main Channel (q1): 8.62 cfs

Unit Discharge in the Constricted Area (q2): 7.22 cfs/ft

D50: 20.330160 mm

Upstream Flow Depth: 1.47 ft

Flow Depth Prior to Scour: 0.05 ft

Result Parameters

q2/q1: 0.84

Average Velocity Upstream: 5.85 ft/s

Critical Velocity above which Bed Materal of Size D and Smaller will be Transported: 4.83 ft/s

Scour Condition: Live Bed

Embankment Length/Floodplain Width Ratio: 0.00

Scour Condition: a (Main Channel)

Amplification Factor: 1.20

Flow Depth including Contraction Scour: 1.49 ft

Maximum Flow Depth including Abutment Scour: 1.49 ft

Scour Hole Depth from NCHRP Method: 1.44 ft

Right Abutment Details

Abutment Scour

Computation Type: NCHRP

Input Parameters

NCHRP Method

Abutment Type: Vertical-wall abutment

Angle of Embankment to Flow: 90.46 Degrees

Centerline Length of Embankment: 0.00 ft

Projected Length of Embankment: 0.00 ft

Width of Flood Plain: 0.00 ft

Unit Discharge, Upstream in Main Channel (q1): 8.62 cfs

Unit Discharge in the Constricted Area (q2): 7.22 cfs/ft

D50: 20.330160 mm

Upstream Flow Depth: 1.47 ft

Flow Depth Prior to Scour: 1.63 ft

Result Parameters

q2/q1: 0.84

Average Velocity Upstream: 5.85 ft/s

Critical Velocity above which Bed Materal of Size D and Smaller will be Transported: 4.83 ft/s

Scour Condition: Live Bed

Embankment Length/Floodplain Width Ratio: 0.00

Scour Condition: a (Main Channel)

Amplification Factor: 1.20

Flow Depth including Contraction Scour: 1.49 ft

Maximum Flow Depth including Abutment Scour: 1.49 ft

Scour Hole Depth from NCHRP Method: -0.14 ft

Bridge Scour Analysis:2080 100yr

Notes:

Scenario: PC_2080_Expected_100yr (SRH-2D)

Contraction Scour Summary

Contraction & Long Term Scour is applied method due to greater scour.

Applied Contraction Scour Depth 0.61 ft

Contraction & Long Term Scour is applied method due to greater scour.

Pressure Scour Depth 0.61 ft

Clear Water Contraction Scour Depth 0.63 ft

Live Bed Contraction Scour Depth 0.61 ft

Applied Contraction Scour Elevation with LTD 0.61 ft

Local Scour at Abutments Summary

Left Abutment

Abutment Scour Method: NCHRP Method

Abutment Scour Depth -0.04 ft

Total Scour at Abutment 0.00 ft

Total Scour Elevation at Abutment 218.66 ft

Right Abutment

Abutment Scour Method: NCHRP Method

Abutment Scour Depth -0.04 ft

Total Scour at Abutment 0.00 ft

Total Scour Elevation at Abutment 218.66 ft

Main Channel Contraction Scour

Computation Type: Clear-Water and Live-Bed Scour

Input Parameters

Average Depth Upstream of Contraction: 1.49 ft

D50: 20.330160 mm

Average Velocity Upstream: 6.24 ft/s

Results of Scour Condition

Critical velocity above which bed material of size D and smaller will be transported: 4.84 ft/s

Contraction Scour Condition: Live-Bed

Live Bed and/or Clear Water Input Parameters

Temperature of Water: 60.00 ºF

Slope of Energy Grade Line at Approach Section: 0.2049 ft/ft

Flow in Contracted Section: 141.98 cfs

Flow Upstream that is Transporting Sediment: 87.37 cfs

Width in Contracted Section: 16.55 ft

Width Upstream that is Transporting Sediment: 9.43 ft

Depth Prior to Scour in Contracted Section: 0.97 ft

Unit Weight of Water: 62.40 lb/ft^3

Unit Weight of Sediment: 165.00 lb/ft^3

Results of Clear Water Method

Diameter of the smallest nontransportable particle in the bed material: 25.412700 mm

Average Depth in Contracted Section after Scour: 1.59 ft

Scour Depth: 0.63 ft

Results of Live Bed Method

Shear Velocity: 3.13 ft/s

Fall Velocity: 1.64 ft/s

Average Depth in Contracted Section after Scour: 1.57 ft

Scour Depth for Live Bed: 0.61 ft

Shear Applied to Bed by Live-Bed Scour: 0.4593 lb/ft^2

Shear Required for Movement of D50 Particle: 0.2669 lb/ft^2

Recommendations

Recommended Scour Depth: 0.61 ft

Left Bank Contraction Scour

Computation Type: Clear-Water or Live-Bed Scour

Input Parameters

Average Depth Upstream of Contraction: 0.85 ft

D50: 0.000000 mm

Average Velocity Upstream: 3.34 ft/s

Results of Scour Condition

Critical velocity above which bed material of size D and smaller will be transported: 0.00 ft/s

Contraction Scour Condition: Live-Bed

Live Bed and/or Clear Water Input Parameters

Temperature of Water: 60.00 ºF

Slope of Energy Grade Line at Approach Section: 0.2049 ft/ft

Flow in Contracted Section: 0.31 cfs

Flow Upstream that is Transporting Sediment: 36.31 cfs

Width in Contracted Section: 1.99 ft

Width Upstream that is Transporting Sediment: 12.83 ft

Depth Prior to Scour in Contracted Section: 0.10 ft

Unit Weight of Water: 62.40 lb/ft^3

Unit Weight of Sediment: 165.00 lb/ft^3

Right Bank Contraction Scour

Computation Type: Clear-Water or Live-Bed Scour

Input Parameters

Average Depth Upstream of Contraction: 0.82 ft

D50: 0.000000 mm

Average Velocity Upstream: 2.16 ft/s

Results of Scour Condition

Critical velocity above which bed material of size D and smaller will be transported: 0.00 ft/s

Contraction Scour Condition: Live-Bed

Live Bed and/or Clear Water Input Parameters

Temperature of Water: 60.00 ºF

Slope of Energy Grade Line at Approach Section: 0.2049 ft/ft

Flow in Contracted Section: 0.49 cfs

Flow Upstream that is Transporting Sediment: 16.25 cfs

Width in Contracted Section: 0.98 ft

Width Upstream that is Transporting Sediment: 9.11 ft

Depth Prior to Scour in Contracted Section: 0.33 ft

Unit Weight of Water: 62.40 lb/ft^3

Unit Weight of Sediment: 165.00 lb/ft^3

Left Abutment Details

Abutment Scour

Computation Type: NCHRP

Input Parameters

NCHRP Method

Abutment Type: Vertical-wall abutment

Angle of Embankment to Flow: 89.08 Degrees

Centerline Length of Embankment: 0.00 ft

Projected Length of Embankment: 0.00 ft

Width of Flood Plain: 0.00 ft

Unit Discharge, Upstream in Main Channel (q1): 9.26 cfs

Unit Discharge in the Constricted Area (q2): 8.58 cfs/ft

D50: 20.330160 mm

Upstream Flow Depth: 1.49 ft

Flow Depth Prior to Scour: 1.71 ft

Result Parameters

q2/q1: 0.93

Average Velocity Upstream: 6.24 ft/s

Critical Velocity above which Bed Materal of Size D and Smaller will be Transported: 4.84 ft/s

Scour Condition: Live Bed

Embankment Length/Floodplain Width Ratio: 0.00

Scour Condition: a (Main Channel)

Amplification Factor: 1.20

Flow Depth including Contraction Scour: 1.39 ft

Maximum Flow Depth including Abutment Scour: 1.67 ft

Scour Hole Depth from NCHRP Method: -0.04 ft

Right Abutment Details

Abutment Scour

Computation Type: NCHRP

Input Parameters

NCHRP Method

Abutment Type: Vertical-wall abutment

Angle of Embankment to Flow: 90.92 Degrees

Centerline Length of Embankment: 0.00 ft

Projected Length of Embankment: 0.00 ft

Width of Flood Plain: 0.00 ft

Unit Discharge, Upstream in Main Channel (q1): 9.26 cfs

Unit Discharge in the Constricted Area (q2): 8.58 cfs/ft

D50: 20.330160 mm

Upstream Flow Depth: 1.49 ft

Flow Depth Prior to Scour: 1.71 ft

Result Parameters

q2/q1: 0.93

Average Velocity Upstream: 6.24 ft/s

Critical Velocity above which Bed Materal of Size D and Smaller will be Transported: 4.84 ft/s

Scour Condition: Live Bed

Embankment Length/Floodplain Width Ratio: 0.00

Scour Condition: a (Main Channel)

Amplification Factor: 1.20

Flow Depth including Contraction Scour: 1.39 ft

Maximum Flow Depth including Abutment Scour: 1.67 ft

Scour Hole Depth from NCHRP Method: -0.04 ft

Appendix L: Floodplain Analysis (FHD ONLY)

Floodplain analysis will be provided at the FHD for SF Johnson Creek at SR 3 MP 50.85.

DRAFT

Appendix M: Scour Countermeasure Calculations (FHD ONLY)

Scour countermeasure calculations will be provided at the FHD for SF Johnson Creek at SR 3 MP 50.85.

DRAFT

Appendix N: Hydrology Calculations

DRAFT

Attachment 1. MGS Flood Input/Output Summary

DRAFT

Jacobs

CLIENT:	WSDOT			DATE:	1/7/2022
JOB TITLE:	WSDOT NW Region Fish Passage - PHD - SR 003/ SF Johnson Creek to Johnson Creek (MP 50-85)	BY:	BI, EIT	JOB # :	W3Y05003; A.P3.EV.991241
SUBJECT:	Hydrology Model Input Computations	CHECKED:	TJ, PE	Sheet # :	1 of 1
Topic:	**MGS Flood Inputs and Output for South Fork Johnson Cr Tributary to Johsnon Cr**				

Contributing Area	
10,563,704	square feet
0.38	square miles
242.5	acres

Pivot Calculations from *South Fork Johnson*

Row Labels	Sum of Pervious Area Calc (ac)
Outwash	**45.1**
Forest	40.7
Grass	4.4
Till	**160.5**
Forest	79.3
Grass	53.9
Impervious	1.8
Pasture	21.5
Wetland	4.1
Wetland	**21.2**
Forest	3.7
Grass	6.6
Pasture	3.4
Wetland	7.6
Grand Total*	**226.8**

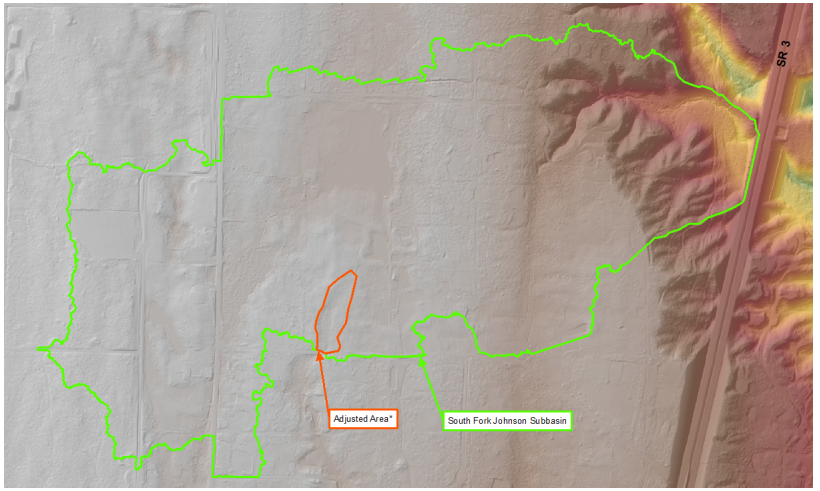
*Does not include impervious area

MGS Flood Input

MGS Soil Classifications	Area (acres)	% of total	Adjusted*	% of total (Adjusted)
Till Forest	79.3	33%	78.8	33%
Till Pasture	21.5	9%	20.0	8%
Till Grass	53.9	22%	53.9	22%
Outwash Forest	40.7	17%	40.7	17%
Outwash Pasture	0.0	0%	0.0	0%
Outwash Grass	4.4	2%	4.4	2%
Wetland	25.3	10%	25.3	11%
Green Roof	0.0	0%	0.0	0%
Impervious	17.5	7.2%	16.8	7%
Total	**242.5**	**100%**	**239.8**	**100%**

MGS Flood Results

Tr (Years)	Discharge (cfs)
2-Year	15
5-Year	23
10-Year	32
25-Year	43
50-Year	57
100-Year	62
200-Year	66
500-Year	72



* Adjusted area removed per Kitsap County stormwater records

Attachment 2. MGS Flood Project Report

DRAFT

MGS FLOOD
PROJECT REPORT

Program Version: MGSFlood 4.54
Program License Number: 200410003
Project Simulation Performed on: 01/05/2022 10:52 AM
Report Generation Date: 01/05/2022 10:53 AM

Input File Name: SFJohnsonCktoJohnsonCk.fld
Project Name: WSDOT OR GEC PHD
Analysis Title: 991241
Comments: MGS Flood Hydrology Computations

PRECIPITATION INPUT

Computational Time Step (Minutes): 15

Extended Precipitation Time Series Selected
Climatic Region Number: 16

Full Period of Record Available used for Routing
Precipitation Station : 96004405 Puget East 44 in_5min 10/01/1939-10/01/2097
Evaporation Station : 961044 Puget East 44 in MAP
Evaporation Scale Factor : 0.750

HSPF Parameter Region Number: 1
HSPF Parameter Region Name : USGS Default

********** Default HSPF Parameters Used (Not Modified by User) **********

********** WATERSHED DEFINITION **********

Predevelopment/Post Development Tributary Area Summary

	Predeveloped	Post Developed
Total Subbasin Area (acres)	239.839	6.000
Area of Links that Include Precip/Evap (acres)	0.000	0.000
Total (acres)	239.839	6.000

----------SCENARIO: PREDEVELOPED
Number of Subbasins: 1

---------- Subbasin : 991241 SF Johnson Subbasin ----------

-------Area (Acres) --------	
Till Forest	78.820
Till Pasture	20.044
Till Grass	53.863
Outwash Forest	40.716
Outwash Grass	4.387
Wetland	25.252
Impervious	16.757
Subbasin Total	239.839

----------SCENARIO: DUMMY
Number of Subbasins: 1

---------- Subbasin : Dummy ----------

-------Area (Acres) --------	
Till Forest	1.000
Till Pasture	1.000
Till Grass	1.000
Outwash Forest	1.000
Outwash Grass	1.000
Impervious	1.000

Subbasin Total 6.000

********** **LINK DATA** **********

----------SCENARIO: PREDEVELOPED
Number of Links: 0

********** **LINK DATA** **********

----------SCENARIO: DUMMY
Number of Links: 0

**********FLOOD FREQUENCY AND DURATION STATISTICS**********

----------SCENARIO: PREDEVELOPED
Number of Subbasins: 1
Number of Links: 0

----------SCENARIO: DUMMY
Number of Subbasins: 1
Number of Links: 0

************Groundwater Recharge Summary **************
Recharge is computed as input to Perlnd Groundwater Plus Infiltration in Structures

Total Predeveloped Recharge During Simulation

Model Element	Recharge Amount (ac-ft)
Subbasin: 991241 SF Johnson Su	45984.690
Total:	45984.690

Total Post Developed Recharge During Simulation

Model Element	Recharge Amount (ac-ft)
Subbasin: Dummy	1201.204
Total:	1201.204

Total Predevelopment Recharge is Greater than Post Developed
Average Recharge Per Year, (Number of Years= 158)
Predeveloped: 291.042 ac-ft/year, Post Developed: 7.603 ac-ft/year

************Water Quality Facility Data **************

----------SCENARIO: PREDEVELOPED

Number of Links: 0

----------SCENARIO: DUMMY

Number of Links: 0

************Compliance Point Results **************

Scenario Predeveloped Compliance Subbasin: 991241 SF Johnson Subbasin

Scenario Dummy Compliance Subbasin: Dummy

***** Point of Compliance Flow Frequency Data *****

Recurrence Interval Computed Using Gringorten Plotting Position

Predevelopment Runoff		Postdevelopment Runoff	
Tr (Years)	Discharge (cfs)	Tr (Years)	Discharge (cfs)
2-Year	15.218	2-Year	0.556
5-Year	23.265	5-Year	0.758
10-Year	31.501	10-Year	0.984
25-Year	43.334	25-Year	1.421
50-Year	56.675	50-Year	1.846
100-Year	61.386	100-Year	2.049
200-Year	65.993	200-Year	2.092
500-Year	72.057	500-Year	2.146

** Record too Short to Compute Peak Discharge for These Recurrence Intervals

****** Flow Duration Performance ******

Excursion at Predeveloped 50%Q2 (Must be Less Than or Equal to 0%):	-100.0%	PASS
Maximum Excursion from 50%Q2 to Q2 (Must be Less Than or Equal to 0%):	-99.9%	PASS
Maximum Excursion from Q2 to Q50 (Must be less than 10%):	-90.0%	PASS
Percent Excursion from Q2 to Q50 (Must be less than 50%):	0.0%	PASS

MEETS ALL FLOW DURATION DESIGN CRITERIA: PASS

****** LID Duration Performance ******

Excursion at Predeveloped 8%Q2 (Must be Less Than 0%):	-100.0%	PASS
Maximum Excursion from 8%Q2 to 50%Q2 (Must be Less Than 0%):	-100.0%	PASS

MEETS ALL LID DURATION DESIGN CRITERIA: PASS

Attachment 3. USGS Regression Method Calculations

DRAFT

Jacobs	CLIENT:	WSDOT		DATE:	1/7/2022
JOB TITLE:	WSDOT PHDs		BY:	BI, EIT	JOB # : W3Y05003
SUBJECT:	Hydrology Model Input Computations		CHECKED:	TJ, PE	Sheet # : 1 of 1

Topic: USGS Regression Method - Unnamed Tributary to Freedom Creek, I-5 SB
from: https://pubs.usgs.gov/sir/2016/5118/sir20165118_floodqtools.xlsm
documentation: https://pubs.er.usgs.gov/publication/sir20165118

Flood Q Regression Tool. Use to estimate flood discharge in Washington State at ungaged sites based on regional regression equations and user-determined basin characteristics.

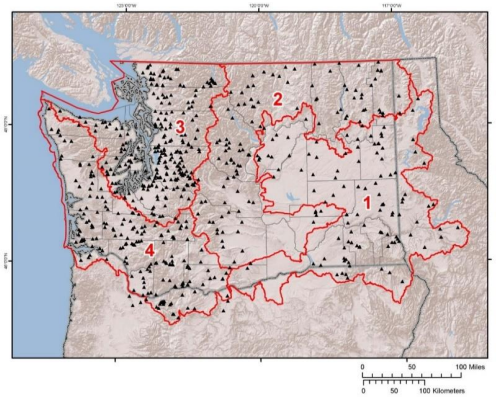
DA = Drainage Area, in square miles; P = Average Basin Annual Precipitation, in inches (from PRISM data set, years 1981-2010); CAN = Percent canopy cover (NLCD 2001); AEP = Annual Exceedance Probability; Qu = Flood Discharge, in cubic feet per second at ungaged site for the indicated AEP; PI_L, PI_U= Predition Intervals (L=Lower and U=Upper)

Instructions for using the Flood Q Tool to estimate Flood Discharges at Ungaged Sites using the regional regression equations

Steps	Instructions
1	Select the Regression Region below from the List Box
2	Determine the drainage area, *DA* and the Annual Precipitation, *P* for the ungage drainage basin. If you pick Regression Region 1 or 2, determine the percent canopy cover, *CAN*.
3	Enter these basin characteristic values in the green-shade cells. If the cell changes to red, than the value is outside the range of valid values for this regression. Valid value range listed to the right of the green cells.
4	Rows 23-30 will have the results. Estimated flood discharge, Qu, will be found in column O and the 90% prediction limits for these flood discharges will be found in columns R and T.

Regression Region 1
Regression Region 2
Regression Region 3
Regression Region 4

Regression Regions in Washington State



User determined basin characteristics for ungaged site

Selected Region: Regression Region 3

			Range of values that are valid for the regression
Drainage Area, *DA*	=	0.38 square miles	0.08 - 2605
Annual Precipitation, *P*	=	41 inches	33.29 - 168.0
Percent Canopy, *CAN*	=	80 %	value not used in regression

Selected Region: Regression Region 3

Estimate of indicated flood discharge for Regression Region 3 using regional regression equations

RI (years)	AEP		*Q_u, ft³/s	Prediction Intervals, 90% confidence level PI_L, in ft³/s	PI_U, in ft³/s
2	0.5	=	8.2	4.1	16.5
5	0.2	=	13.1	6.4	27.0
10	0.1	=	16.5	7.9	34.4
25	0.04	=	20.9	9.6	45.5
50	0.02	=	24.1	10.7	54.1
100	0.01	=	27.7	12.1	63.5
200	0.005	=	31.2	13.1	74.3
500	0.002	=	36.1	14.5	90.0